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(PROJECT HI-MOVE - 1964 FINAL REPORT)

(ORGANIC AND ASSOCIATED TERRAIN RESEARCH UNIT)
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PROJECT HI-MOVE – 1964

FINAL REPORT

Submitted by
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PREFACE

It is now recognized internationally (by the International Society for Terrain Vehicle Systems) that mobility and trafficability are related terms implying evaluation in three areas: aspects of vehicle design; physical constitution and properties of terrain; and type of operation. Accordingly, an estimate of the degree of success in achieving off-the-road mobility must recognize these three areas.

Project Hi-Move 1964 was initiated on this philosophy and the practice of isolating activity to one or another area was for convenience only. Integration of results is made in the text of this report where pertinent.

As reported previously (1), three factors limited successful vehicular performance. The first was vehicle design, evidenced by mechanical breakdown and inability of a vehicle to endure in the conditions and environment of organic terrain. The second, the influence of water as a component of organic terrain and its environment, contributed in a major way to immobilization and performance deficiency. The type of field exercise undertaken also imposed severe limitation on vehicle response and constituted the third limiting factor.

In the present set of tests, the first limitation, mechanical deficiency, was re-examined by emphasizing wheeled vehicles in the testing program. Vehicles with wheels and pneumatic tires operate more successfully and with less down-time than tracked vehicles on mineral terrain. Apart from the preliminary work of OATRU (2), no experience has been available for wheeled vehicles on organic terrain.

In planning the tests on wheeled vehicles, the second limitation — water — became important. Suitable low-water-regime muskeg, appropriately distributed, had to be found to allow for wide use of wheeled vehicles. Much of this terrain exists. It consists of various peat types and can usually be detected from air photographs. Accordingly, a number of relatively dry muskeg types were introduced into the testing activity. For the first time, it became possible to test tracked and wheeled vehicles side by side on muskeg.

The third control on performance, design of the exercise, was planned for broadest effect. The procedure had to be standardized, but it was possible to extend field exercises this year into forested areas, and to place more emphasis on exercises in which availability of more power could be exploited. Surface obstruction (topography and cover) and resistance to thrust induced through sinkage played a larger role in the testing this year than in 1963.

Against the above background, the objective of Project Hi-Move 1964 will perhaps be better appreciated.

It remains to be emphasized that this investigation is a product of inter-disciplinary study. Terra-dynamics properly involves engineering to which mechanical, civil, instrumentation engineering, and terrain interpretation contribute. The author acknowledges the association of his colleagues, especially K. Ashdown, (Manager), W.B. Newcombe, J. Siddall, N.E. Wilson and J. Radforth, (Engineering Assistant), as well as graduate students Miss L. Usik, W. Brideaux, R.W. Menzies, J. Wilfong, and R. Sumner, (Vehicle Operator).

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Mr. K. Ashdown prepared this report, and in its revised form it is submitted by the members of OATRU.

Norman W. Radforth,
Chairman, OATRU.

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TERRAIN DESCRIPTION AND SIGNIFICANCE

In conformity with previous reports of this nature, description of terrain will be conveyed by the use of the Radforth classification system (3).

The primary elements of the system are nine classes of surface vegetation differentiated on the bases of height, structure, and growth habit. Briefly, these are:

Class	Example
A — Trees over 15 ft.	Spruce, Larch
B — Trees under 15 ft.	Spruce, Larch
C — Grasslike over 3 ft.	Reeds, Sedges
D — Bushes over 2 to 3 ft.	Alder, Willow
E — Bushes under 2 to 3 ft.	Leatherleaf, Labrador Tea
F — Grasslike under 3 ft.	Sedges, Cottongrass
G — Individual herbaceous plants	Lilies, Pitcher Plants
H — Lichens	
I — Mosses	

An appreciation of the terrain, under the circumstances of almost any engineering application, is related to such things as surface obstructions or hazards, differences in bearing capacity, or differences in rates of deterioration of foundation material, and the classification system enables assessment of such factors to be made.

Vegetation classes do not occur singly except in rather small patches, but neither do they occur in all possible combinations.

For the purposes of the test program, only four combinations or 'categories' were considered. These recur not only all across Canada, but in both north and south temperate zones, on a circumpolar basis and in humid tropical regions.

'FI' categorizes organic terrain where the vegetation is predominantly short and grasslike with mosses providing the ground cover. An area of FI is usually quite flat, but may, if hummocky, present obstructional hazards to small vehicles. The moisture regime is usually medium to high and, in some areas, the vegetation may extend as a 'floating mat' over water or very fluid peat.

The peat below living vegetal cover is usually composed of the remains of plants similar to those on the surface, and that below FI is therefore non-woody, fine fibrous, and largely amorphous-granular in structure, as elements are readily broken down by various natural agencies.

By implication, therefore, the categorization 'FI' also indicates an area low in bearing capacity and subject to rapid deterioration under traffic. The surface vegetation is friable, the peat is of low fibrosity, and a usually high water content is conducive to rapid 'slurry' formation.

Most vehicles will have difficulty in this terrain.

'EI' categorizes organic terrain where the predominant cover comprises low bushes, and mosses provide the ground cover. Where bushes are contiguous, the topography is reasonably flat, but where there is separation, mounding occurs. The mounds have as their core the branch structure of the bushes, but much of the bulk is contributed by compact moss growth. Sometimes ice can persist in the centers of such mounds well into early summer and create unsuspected hazards.

When separation between mounds is marked, FI may be found in the hollows, and provide localized areas of low bearing capacity. An area of EI otherwise provides good initial bearing capacity, because of the woody fibrous structure of the underlying peat and of the interlocking meshwork of living and recently incorporated plant material sometimes referred to as the 'surface mat'. The woodiness of the material and the strength of the fibers also provide good resistance to deterioration by abrading or shearing forces.

EI areas near water may be of the 'floating mat' kind, and care must be taken in crossing them.

'DI' offers difficulty because of the high resistance of the class 'D' bushes and of the low bearing capacity of the peat between bushes. Spacing is in the order of 6 to 8 ft., there are upwards of 6 vertical branches about 1 to 2 in. in diameter to each bush and, if there is not already open water in the area, the peat will be very fluid or soon made so by the wallowing of the vehicle. If the height and distribution of bushes is appropriate, a vehicle may be able to bridge 'traps' by crushing branches beneath it.

AEI-ADI areas are characterized by trees over 15 ft. forming the predominant class in otherwise EI or DI areas. Because the peat has the remains of similar trees incorporated in it and because, as the tree growth indicates, conditions are drier, the peat is a little firmer than that found in EI or DI areas. A vehicle's progress depends on the ease with which it can be steered to avoid the trees, or its capability to override or push the trees aside.

In areas where several categories are found, difficulties may be encountered at zone boundaries. A vehicle may not be able to make the transition from a deeply rutted FI area to an EI area because it is unable to surmount the bushes, root systems, and coarse peat that make up the surface mat edge; it may not be able to surmount a surface mat edge from a free floating position in open water, and difficulties may also arise at an AEI-ADI, EI-DI or FI-DI boundary. Several zonal boundaries were included in the cross-country route around Dinner Lake as tests of transitional capabilities of vehicles.

VEHICLE DESCRIPTION

It was convenient to test the vehicles in small groups, and each group had a common feature of size, morphology, or engineering principle to facilitate comparisons.

The first group comprised the XM571, RN10, and Land Rover tracked vehicles.

The XM571 is an articulated tracked vehicle (Fig.7) weighing 4,871 lb. and having a payload capacity of 2,000 lb. The length is 234 in. and the width 64 1/2 in. Construction is mainly of welded aluminum reinforced sheet. The vehicle is amphibious and has a freeboard of 8 in. when fully loaded.

The RN10 is a tracked vehicle (Fig. 8) weighing 2,600 lb. with a payload capacity of 1,000 lb. It is 125 in. long and 78 in. wide. The hull is of fiberglass construction. It is described as a 'floater', and a small outboard motor is used for water propulsion.

The Land Rover is fitted with Cuthbertson tracks to convert it to a four-tracked vehicle (Fig. 9). It weighs 7,500 lb. and, for the test, was loaded with 1,000 lb. Dimensions are 156 in. by 108 in. The vehicle is fitted with buoyancy pontoons and the engine is fully waterproofed, but the vehicle has no provision for travel in water.

The second group consisted of a Jeep and a Volvo Laplander.

The Jeep (M38A1) (Fig. 10) is the well-known personnel and general utility vehicle. It weighs 2,840 lb. and has a payload capacity of 625 lb. It is 139 in. by 61 in. The engine of the test model was waterproofed.

The Volvo Laplander (L3314N) (Fig. 11) is also a four-wheel drive vehicle. It weighs 3,570 lb. and carried a payload of 1,000 lb. for test purposes. It is 159 in. by 65 in. It is not amphibious, and the test model was not waterproofed.

Three articulated-frame wheeled logging vehicles comprised the next group.

The Tree Farmer, Model C5B Carrier (Fig. 12) weighs 10,010 lb. and was loaded with 4,000 lb. It is 195 in. by 108 in. The four tires are 23.1 x 26 Goodyear traction sure-grip.

The Timberjack, Model 230 (Fig. 13) weighs 12,000 lb. and carried a load of 4,000 lb. It is 198 in. by 104 in. The four tires are 18.4 x 34 Goodyear traction sure-grip.

The Iron Mule (Fig. 14) weighs 11,450 lb. and was loaded with 1,000 lb. for the test. It is 240 in. long and 86 in. wide. The four tires are 16.9 x 24 Goodyear traction sure-grip.

Two vehicles comprised the last group, the Rat and the Jiger.

The Rat (CL70) (Fig. 15) weighs 1,500 lb. and carried 300 lb. during tests. It is 157 in. by 48 in. It is amphibious and is constructed of aluminum sheet.

The Jiger (Fig. 16) is a six-wheeled twin-engined vehicle weighing 278 lb. with a capacity of 400 lb. It measures 76 in. by 51 in. It is amphibious, and auxiliary propulsive water jets may be used to improve travel in water. The hull is of fiberglass.

Two experimental vehicles were also tested.

The Airoll (Fig. 17) is a roller-track vehicle weighing 5,900 lb. It is amphibious. The Canadair Fisher tested under similar circumstances in 1963 has a similar tractive principle, and some aspects of performance will be compared in the following report.

The Hovertruck (Fig. 18) is a standard Land Rover equipped with a blower and skirt arrangement to provide a ground cushion effect. It weighs 8,260 lb. and the dimensions are 217 in. by 104 in.

The Gemini (Fig. 19) is an experimental test bed of a ground-effect machine (4). Test results appear in Appendix 3.

REFERENCES

1. OATRU 1963 Mobility Research on Small High-Mobility Vehicles.

2. OATRU 1963 Project Timberjack.

3. Radforth, N.W. Suggested classification of Muskeg for the Engineer. Nat. Res. Council ACSSM Tech. Mem. 24, 1953.

4. OATRU 1963 Project GEMINI.

PLAN AND PROGRAM OF TESTS

The testing schedule required that the vehicles be subjected to mobility tests on four types of organic terrain, and also to tests on associated terrain. Accordingly, four test sites were selected in areas of FI(E), EI, DI, and AEI-ADE, and a cross-country course approximately 1 1/4 mi. was established. At each test site, each vehicle was provided with a test lane 100 ft. by 50 ft. in which all tests were to be performed.

Vehicles were grouped according to similarity of mechanical features, general morphology, purpose or size, and an attempt was made to complete testing on organic terrain on a group basis before subjecting all vehicles to the cross-country course. The latter provision was made so that a large group of observers could gain an appreciation of the performance after the vehicle operators had gained experience in a variety of conditions.

The program for the period from 17 to 29 August, 1964, was adhered to insofar as vehicle availability and serviceability permitted and, in addition, several ad hoc tests were conducted.

Test Sites

An area of organic terrain adjacent to Cranberry Lake, Nobel, Ontario, contained suitable FI(E), EI and DI sites, and a small area of AEI-ADE was found about one mile from Highway 69. The cross-country course was laid out around Dinner Lake — approximately two miles to the west (Fig. 1).

A former explosives compound on the property of Canadian Industries Ltd. was used for vehicle storage, fueling, and loading, and a route from this point to Cranberry Lake was prepared and measured. It was therefore possible to obtain speed and fuel consumption data for each vehicle over a typical stretch of associated mineral terrain, in addition to those available from the Dinner Lake circuit.

The FI(E) site was separated from the lake by a rock ridge, and was roughly contained by other rock ridges to the north, east, and south (Figs. 3 and 4). The peat was approximately 8 ft. deep and underlain by 4 to 6 ft. of silt. The moisture regime was medium, and the peat an amorphous-granular, non-woody, fine-fibrous type.

The EI site was a few hundred yards to the north of the FI(E) site and adjacent to the lake (Figs. 3 and 4). It was intersected by several water channels but, in setting out test lanes, these were avoided as much as possible. The area was very wet and the amorphous-granular, non-woody, and woody fine-fibrous peat was over 15 ft. deep.

The DI site was situated near the entrance of Blair Creek into Cranberry Lake (Figs. 3 and 5), and 3 1/2 ft. of peat lay on a silt-sand-peat base. The D elements varied from 4 to 8 ft. in height, and were spaced 3 to 6 ft. center to center.

The AEI-ADE site lay half a mile east of the compound (Fig. 1). The trees ranged from 4 to 10 in. in diameter and were spaced 6 to 8 ft. apart (Fig. 6). The amorphous-granular, non-woody coarse fibrous peat was approximately three feet deep and lay on a sand-silt base 5 ft. in depth.

The cross-country course around Dinner Lake for amphibious vehicles was the same as that used for small high-mobility vehicle trials in 1963, but an alternative course was chosen for wheeled vehicles with limited fording ability (Fig. 2).

For the Gemini phase of this project a water area with a shallow gradient entry was provided, and further ground-effect tests were conducted in Area 10G (Figs. 1 and 19).

TEST RESULTS

Organic Terrain — FI(E)

The first vehicles tested in FI(E) conditions were the RN10 and XM571 and neither had any difficulty in completing 40 passes. The surface mat was not greatly damaged by either vehicle, although the XM571 tracks cut about 2 inches deeper (Table 1) and were prone to collect vegetation (Fig. 20). Compressional effects (Table 2) were similar. On tight turns, the RN10 inner track sometimes jumped a rear sprocket tooth, and the XM571 inner tracks would slacken (Fig. 21). Inner ruts of the turns were deeper than outer, and surface vegetation more abraded. In an FI test lane of high-water regime the vehicles experienced no difficulty, and compression was similar to that in FI(E).

The tracked Land Rover completed 32 passes, although producing 6-in. ruts along most of the test lane. Most difficulty occurred where a patch of I intruded and, as this was thought to give an anomalous result, the vehicle was allowed to continue testing in the FI(E) portion. At 40 passes, immobilization seemed imminent, and tests were continued until, on the 49th pass, the vehicle had to be recovered by the Water Buffalo. Penetrometer indices were similar to the above. Subsidence values (Table 1) do not reflect conditions at the site of immobilization, where the surface mat was completely removed and the vehicle unable to obtain traction on the remolded amorphous-granular peat below (Fig. 22).

The Jeep was immobilized in a patch of I before reaching the test lane (Fig. 23). It was recovered and was immobilized again on the 16th pass while in reverse. Ruts appeared quickly and steering difficulty occurred because the underside of the vehicle was dragging. The lower indices after traffic (Table 2) and the average subsidence of 9 in. indicate the extent of remolding and rut formation.

The Volvo was temporarily immobilized during the 18th, 22nd and 27th passes, but was recovered without assistance by being rocked back and forth. After the last self-recovery it was immobilized on the 28th pass while in reverse (Fig. 24). The effect of elements of E was demonstrated by a moderate pitch and roll movement of each of these wheeled vehicles, but the Volvo showed a more pronounced response to surface irregularities. Lower indices again showed after traffic (Table 2), but rutting was not as pronounced as for the Jeep.

The effect of elements of E was demonstrated by a moderate pitch and roll movement of each of these wheeled vehicles, but the Volvo showed a more pronounced response to surface irregularities because of its softer suspension.

Three articulated wheeled logging vehicles were tested next.

The Tree Farmer had no difficulty in completing 20 passes, but then there was rapid deterioration at several points along the test lane and immobilization occurred on the 38th pass (Fig. 25). Prior to this it had recovered from incipient immobilization by partial application of frame oscillation, but this was discouraged by the OATRU project officer and not fully utilized until immobilization. It then failed to extricate the vehicle because vegetation and peat were pushed aside by the spinning wheels. Rut depth was up to 18 inches. Indices increased after traffic (Table 2).

The Timberjack arrived at the test site with a load of 12,000 lb. and was immobilized before it reached the test lane. (Fig. 26). In recovery operations, by the Water Buffalo, the vehicle could not regain the surface and was dragged for 100 yd. or more leaving a 3-ft. trench. Once on rock it was driven to Macklaim Construction Co. Ltd. to have 8,000 lb. of load removed. On its return it was again immobilized before reaching its test lane. It was recovered by the Water Buffalo and made 10 passes before the surface mat was broken through and the peat below began to appear in the ruts. The holes deepened and the vehicle was immobilized on the 15th pass. Oscillation of the articulated frame did not effect recovery and the vehicle was pulled out by the Water Buffalo. The remolding produced by oscillation and recovery procedures made it impossible to obtain reliable penetrometer data after traffic.

The Iron Mule also failed to reach its test lane on the first attempt and had to be recovered from a patch of I and towed to the test lane by the Water Buffalo. On the second pass it was in difficulty, was immobilized on the 3rd pass and was recovered by the Water Buffalo. Recovery procedures again made it impossible to obtain penetrometer data after traffic.

Neither the Rat nor the Jiger experienced any difficulty in the FI(E) condition and did very little damage to the surface vegetation. There was no appreciable subsidence and no change in penetrometer values.

The Airoll was tested in FI(E) at the edge of Dinner Lake. It completed 50 passes easily although there was a tendency for peat and surface material to build up on the roller drive sprockets (Fig. 27) and, on one occasion, to force the chain off the sprocket. Backwards and forwards maneuvering replaced the chain. The area is much wetter than the FI(E) at Cranberry Lake and the peat became quite fluid. The surface mat also is deeper than that of the test lanes at Cranberry Lake so that even when ruts had reached a depth of 18 in. the vehicle still gained some support from fibrous material.

The Hovertruck was tested in FI(E) in Area 10G and completed 26 passes before the fan drive belt disintegrated. (This failure also occurred during a preliminary test). Ruts about a foot deep formed and shredded vegetation blocked the radiator, partially blocked the air intake (Fig. 28) and, when the vehicle stopped, burned on the exhaust.

The addition of wheeled vehicles to the program necessitated selection of an FI or FI(E) test area of low to medium water regime and of moderate to high bearing capacity, so that immobilization would not occur immediately. The fact that some wheeled vehicles had difficulty reaching the test lanes and made few passes indicates the marginal conditions prevailing.

VEHICLE SPEEDS

Speed tests were conducted in FI(E) test lanes, as these were accessible to all vehicles other than the experimental models.

Results are given in Table 3.

Organic Terrain — EI

During the first 20 passes the XM571 crushed the vegetation and made good progress with some rolling on mounds and hollows. A hole developed where a water-course crossed the test lane and eventually deepened to 3 ft. On backing through the hole, the rear section was lifted by the front section and the tracks became slack for a moment. The vehicle suspension was fitted with 3G torsion bars; 4G bars might have prevented this slackness. The test continued, but terminated at the 46th pass because the vehicle was shipping water in both sections when negotiating the hole (Fig. 29). The fibrous mesh of the surface mat was approximately 3 ft. thick and much of it was compacted below the vehicle, contributing to its successful passage. In such a coarse fibrous peat, changes in penetrometer values can only reflect interstitial or matrix conditions.

The RN10 was tested in an adjacent lane and experienced no difficulty during 40 passes. There was some pitching, especially in the extension of the water-course hole (Fig. 30). Testing was continued to 50 passes. The vehicle rode the surface irregularities well, though pitching and rolling was more pronounced than that of the XM571.

The tracked Land Rover entered the lane and rolled and pitched as the previous vehicles had for the first few passes, but then began to roll rhythmically on its suspension while the individual track units successively accommodated to irregularities (Fig. 31). As the test progressed, the irregularities and the rhythmic rolling became more pronounced until the vehicle became temporarily immobilized on the 49th pass. It recovered traction only to be immobilized on the 51st pass. It was found later to have four flat tires.

An attempt was made to get the Jeep to the EI test site, but it foundered so badly in the water-course complex that it was decided to test it and the Volvo in EI of lower water regime.

The peat in the new EI test site was about 18 in. deep and reasonably firm. Initial firmness and compaction of the surface mat is indicated by penetrometer values (Table 2). The main obstruction to vehicle progress was the mounds, and both vehicles pitched and rolled violently enough to cause the drivers to proceed at a slow pace. Both vehicles completed 40 passes.

The three logging vehicles were tested in the original EI site.

The Tree Farmer was in difficulty in a water-course on its first pass, but backed out. Testing was continued on a shortened lane and the vehicle progressed satisfactorily until the 10th pass. It extricated itself, was temporarily immobilized on the 11th and was fully immobilized on the 12th pass, when a fitting on the orbital steering hydraulic line burst and the oscillating frame action could not be used. It was recovered by the Water Buffalo.

The Timberjack foundered on its way to the lane (Fig. 32) and was recovered by the Water Buffalo. It completed eight passes reasonably well. There was some rolling on mounds and hollows, and rut depth increased to about 1 ft. Conditions deteriorated until the 12th pass, when the test was discontinued because the Water Buffalo was not available for recovery. It was thought that immobilization might have occurred within the next five passes.

The Iron Mule negotiated the lane reasonably well, but was immobilized on the 3rd pass. It was recovered and testing continued on a shortened lane. However, it managed to complete only two more passes and testing was discontinued.

The Rat and Jiger were not tested because they were not available until after the main program had ended and no recovery vehicle was then present at the EI site. However, their performance on EI muskeg is known; each will pitch and roll if a mound condition exists, each may be in difficulty if there are water-courses or holes in wet EI, but both are sufficiently maneuverable and light to have little other difficulty in this kind of cover.

The Airoll was not tested on EI as it arrived late in the test period, was unserviceable on arrival, and could be subjected only to ad hoc tests on the organic terrain that borders Dinner Lake. It traveled well over EI in this area, but the pronounced pitching precluded speeds above about 5 m.p.h.

The Hovertruck was not tested on EI because it could not enter such an area at Dinner Lake owing to obstruction of the skirt by vegetation.

All vehicles had to pass through the relatively dry area of EI where the Jeep and Volvo were tested, and none had difficulty. After two weeks of constant use the trail was not badly damaged.

The main EI site presented extremely difficult conditions. The Water Buffalo was immobilized at one point (Fig. 33), and winched itself out. The variation in strength of the surface mat and the presence of mounds, hollows, and channels is well demonstrated by the pitching and rolling of vehicles seen in the film made during the trials.

Vehicles were immobilized either because their initial ground pressure was higher than the bearing capacity of localized areas within the site (hollows or hidden channels), or because the pitching and rolling action of the vehicles amplified existing variation in bearing capacity. Increasing pitch and roll of the Land Rover was noted as testing proceeded.

Organic Terrain — DI

The XM571 had little difficulty apart from pitching and rolling, especially where a water-course crossed the lane (Fig. 34). It completed 18 passes of 100 ft., but the hole at the water-course prevented testing beyond station 60. Testing was continued up to this point, and 40 passes were completed.

The RN10 completed 40 passes in an adjacent lane and successfully negotiated the water-course each time at slow speed. The vehicle pitched and rolled, but had no real difficulty except in breaking down vegetation.

The tall bushes and firm clones were more easily negotiated by the XM571, but both drivers had inadequate protection from flexed branches.

The tracked Land Rover had difficulty staying in the lane initially because of the 'coalescing traps' between elements of D. It was immobilized on the 22nd pass in the water-course, was recovered and continued testing in a shortened lane. It was immobilized in an area bare of D elements near the beginning of the lane. Much of the difficulty was caused by overhang of the front and rear hitches and pontoons (Fig. 35). The ruts in each area of immobilization had entered the underlying sand and no reliable after-traffic penetrometer values could be obtained.

The Jeep and Volvo could not be taken to the original DI area and were tested in an area adjacent to the Jeep-Volvo EI site. The peat was about 18 in. deep, over sand. Penetrometer values indicated the firmness of the peat and compaction after traffic.

The Volvo commenced by making all passes in one direction, to avoid difficulties that might occur when travelling 'against the grain' of broken-down vegetation. After 10 passes it continued normally and completed 40 passes. The vehicle rolled and pitched on mounds, elements of D, and fallen tree trunks. The winch, which is situated beneath the vehicle chassis, was rendered inoperative when the cable was snagged and unwound.

The Jeep was immobilized on a log on the first pass, was recovered by the Volvo, and continued in a shortened lane. It completed a further 8 passes and then was withdrawn for lack of

time. It rolled and pitched quite violently and the tests had to be conducted at slow speed, but there was no sign of serious deterioration of the surface and it is thought that it could have duplicated the Volvo's performance.

The logging vehicles were tested in the original DI test site.

The Tree Farmer was immobilized on the 6th pass in a continuation of the water-course that had given trouble to the XM571, RN10 and tracked Land Rover. It was recovered by the Water Buffalo and testing was continued on a shortened test lane. It was immobilized again on the 30th pass with the wheels bringing up sand and peat. It was again recovered by the Water Buffalo. No penetrometer data were obtained after traffic.

The Timberjack was not tested in DI as it was immobilized in another area at the time the Tree Farmer and Iron Mule were being tested and it was not practicable to return later with a recovery vehicle to complete the tests. In addition, the Timberjack's performance in DI had been evaluated in previous vehicle trials (2) as follows. "....the vehicle made 11 passes before becoming immobilized. Pitching and rolling due to the presence of traps was marked and the action of the front axle in roll and the articulated frame in oscillation were well demonstrated."

The Iron Mule foundered twice in FI(E) en route to the site and was recovered by the Water Buffalo. It sank again in a patch of FI while turning into the test lane and was again recovered by the Water Buffalo. It was immobilized on the 3rd pass in a coalescing trap. On leaving the test site it was immobilized again in a dry beaver channel about 3 ft. wide.

The order of success of these vehicles was the same as in FI(E) and EI, and tempts one to ascribe differences in performance to tire size, but other variables such as weight, configuration, and driver ability require investigation before conclusions can be reached.

The Hovertruck and Airoll were not tested in DI because it was not possible to take either to such an area.

The Rat and Jiger were not tested in DI for the reasons given under 'Organic Terrain — EI'. The performance of each in DI is known to depend on frequency and distribution of D elements and traps, the steerability of the vehicle and, perhaps most important, the weight of the vehicle as a factor in breaking and surmounting heavy brush.

A greater depth of peat, in some parts of the site, denser brush and a higher water regime would have increased the difficulties presented by this site, but conditions could not have been very much worse, and vehicle performances may be regarded as typical for this category of organic terrain.

Organic Terrain — AEI-ADE

The cover in the test area was not uniform throughout all test lanes, and the above designation indicates the range of conditions. Each test lane will be categorized separately, and significant differences likely to affect mobility will be pointed out.

The test lane used by the XM571 was mainly of AEI cover with some AFI at the entrance and ADI at the end. Trees were 6 to 8 ft. apart and 2- to 6-in. in diameter. The vehicle was able to knock down trees up to 5-in. in diameter after several attempts (Fig. 36). Some difficulty was experienced in maneuvering through 180 degrees at the end of the test lane, because of the length of the vehicle and limited steering. No subsidence was noted, and the vehicle was withdrawn after 8 passes because its ability had been demonstrated and the original surface obstacles had, to a large degree, been eliminated.

The RN10 lane had a few feet of AFI at the entrance and the remainder was AEI. On the first pass, the vehicle knocked down 2- to 3-in. trees, but on the second pass was hung up on an inclined 4 1/2-in. tree that was supported by two adjacent 2-in. trees. It was backed off and

continued to travel well until the 4th pass, when another attempt to knock down the group of three trees failed and resulted in the right-hand track running off the front wheel. The track was replaced when the vehicle was reversed. The vehicle had lost its windshield in a mishap, and the driver was unprotected from overhanging branches. In view of this and the sufficiency of the demonstration, no further passes were attempted.

The tracked Land Rover was not tested in treed muskeg because of the possibility of sustaining damage to the body and pontoons.

The Jeep made two passes in a test lane that was predominantly AEI with some AFI at the entrance. It failed to knock down 2- to 3-in. trees, and was driven around such obstacles. Visibility from the driver's seat, especially to the rear, was too poor to allow avoidance of stumps and logs and maneuverability was limited.

The Volvo ran through AFI for the first half of the lane and then through ADF, but conditions were not too different from the previous lanes. The vehicle was able to knock down 2-in. trees, but failed on 3- and 4-in. trees. The poor visibility to the rear made reverse maneuvering difficult.

The three logging vehicles had no difficulties in treed muskeg. Each had the benefit of a hydraulically operated blade.

The Tree Farmer ran through AFI for most of the lane and into a patch of ADF at the end. It made no deviations, and was able to knock down and surmount trees from 4- to 9-in. in diameter. It had to back off some of the larger root systems that were pulled from the muskeg when a tree was toppled, but it did not avoid them entirely. The vehicle exhibited less pitching and rolling than the other two logging vehicles, although the topography of the lanes was comparable.

The Timberjack lane had the same cover distribution as that of the other two logging vehicles, except for a little ADE at the far end. The vehicle made no stops or deviations on its first pass and knocked down everything in its path. On succeeding passes, it was able to uproot 12-in. trees, but needed to back off several times in order to accomplish this and afterwards to surmount the root system.

The Iron Mule lane had cover similar to that of the Tree Farmer. It was able to knock down 3- to 4-in. trees, but was unable completely to uproot and surmount 6- to 7-in. trees.

The Hovertruck, Airoll, Rat and Jiger were not tested in the AEI-ADE area because they either could not reach it or there was insufficient time. However, the performance of the Rat and Jiger in similar areas of treed terrain depends on the relation between the spacing of the trees, the dimensions of the vehicle, and the steerability of the vehicle. In ADE, the Rat would have a weight advantage over the Jiger, and be able to crush sturdier elements of D.

Water Trials and Mat Mounting

The XM571 was able to enter and leave Cranberry Lake from a sloping rock shore without difficulty. Steering control was not positive and maneuvers in water were not precise, but no doubt would become better with driver practice (Fig. 37). Average speed was 1.3 m.p.h. The vehicle mounted the edge of an EI mat successfully because it rode on submerged peat before reaching the edge (Fig. 38). Later, during the cross-country trials, it was seen that the XM 571 cannot mount an abrupt muskeg margin from a free-floating position because the tracks fail to gain purchase on the mat surface.

The RN10 was also able to enter and leave the lake from a rock shore without difficulty. Without auxiliary propulsion, maneuvers in water were extremely difficult to perform. Slight gusts of wind would throw the vehicle off course and the steering was inadequate for positive

control of direction. A small (5 1/2 h.p.) outboard motor improved steering (Fig. 39) and speed, but both were inferior to the performance of the XM571. Speeds without the outboard motor: 0.77 m.p.h.; with motor: 1.25 m.p.h.

In attempting to mount an EI mat the vehicle rode up on a submerged obstacle, backed off, shipped water over the stern and sank (Fig. 40). It was retrieved by the Water Buffalo (Fig. 41). The windshield was damaged beyond repair (Fig. 42) and a spring shackle on the suspension needed to be welded, but the engine and transmission functioned normally after being drained, dried and replenished with oil.

The Rat's maneuverability was similar to that of the XM571, regardless of the water rudder being in or out of the water. Speed was 2.2 m.p.h. The vehicle cannot always mount the abrupt edge of a mat from a free-floating position, but is able to climb steep rock slopes from water (Fig. 43).

The Jiger is quite maneuverable, but is more susceptible to wind and water currents than any other vehicle tested. The use of auxiliary propulsive water jets increases steerability and speed. Speeds without jets: 1.0 m.p.h.; with jets: 2.9 m.p.h. It has little difficulty mounting mat edges unless it encounters tall shrubs.

The Airoll was subjected to ad hoc tests in Dinner Lake (Fig. 44). No speed tests were performed. It seemed to be capable of speeds between 2 and 3 m.p.h. Its performance on water was similar to that of the Fisher, described in a previous report on small high-mobility vehicles. The tendency for the vehicle to turn in a direction opposite to that in which it was being steered was more marked than in the case of the Fisher and is being examined. The vehicle had little difficulty in mounting mat edges although it tipped alarmingly.

Vehicle performances in water are summarized in Table 4, and the film accompanying this report provides examples of performance.

Light winds prevailed throughout the water trials and there was no discernible current, but the maneuverability and low speeds attained by all vehicles cast doubt on their ability to operate in exposed areas or swift currents. Freeboard allowance of each vehicle (except the Jiger and Airoll) would seem inadequate for operations in 'choppy' waters or where submerged obstacles might be encountered. In addition to the sinking of the RN10, it will be remembered that the XM571 tests in EI were discontinued because it too shipped water.

Cross-Country Trials

See Fig. 2 for details of routes.

The XM571 was able to negotiate all obstacles on the mineral terrain (Fig. 45), was able to enter water from rock ledges, to negotiate beaver channels and dead-fall strewn muskeg, but it failed to remount muskeg from water. The low average speed and high fuel consumption shown in Table 5 reflect the time spend seeking a place to mount the mat and the many attempts made.

The RN10 proceeded at a much slower pace and was not able to tackle all obstacles on mineral terrain because of the danger of turning over. It performed well on muskeg except in remounting the mat margin of a beaver lodge pool (Fig. 46) and again at the edge of the muskeg adjacent to Highway 69. This vehicle also lost time at the mat edge and, although the tank was inadvertently 'topped up' before a fuel consumption figure could be obtained, it is thought that it would have been high.

The tracked Land Rover was not taken over some obstacles on mineral terrain because of the possibility of upset. It negotiated organic terrain well until it encountered a small area near the duck-blind (Fig. 2). The rear track units struck a hidden rock face and were badly damaged during recovery operations (Figs. 47 and 48).

The Jeep and Volvo performed in almost identical manner, both negotiating all obstacles until reaching the beaver channel on the east side of the lake (Figs. 2 and 49). Both were retrieved and continued without incident to complete the course. The Volvo driver appeared to have a more comfortable ride. Average speeds (based on running time) reflect the slow rate of progress imposed by course conditions, but the fuel consumption figures are affected by several minutes idling time and by repeated attempts to extricate vehicles from the beaver channel.

The Tree Farmer appeared to be the outstanding vehicle of the three logging tractors. It negotiated every obstacle and completed the course with an average speed of about 9 m.p.h. Much of its success was attributable to the competence and aggressiveness of its operator.

The performances of the Timberjack and Iron Mule were similar. Each was able to complete the course to the place where the Land Rover had become immobilized and then each foundered. The small area concerned had borne a lot of traffic and was difficult to negotiate, but the last two immobilizations were also related to driver ability. The Tree Farmer driver knew and exploited the capabilities of his vehicle to a greater extent than the others, and also seemed to have acquired a better understanding of trafficability potential of organic terrain.

The Jiger (Fig. 16) and the Rat (Fig. 15) completed the course with little difficulty. The driver of the Jiger dismounted at several obstacles and operated the vehicle from outside. It mounted mat edges well, but in later ad hoc tests it had difficulty when carrying an extra person. The Rat made several unsuccessful attempts at mat edges, but was never immobilized.

The Hovertruck and Airoll were not subjected to the cross-country trial.

Vehicle speeds and fuel consumptions for the Dinner Lake circuits and for the course on mineral terrain from the C.I.L. storage compound to Cranberry Lake are given in Tables 5 and 6, respectively. Times were not obtained for the tracked Land Rover, Jeep, and Volvo, but they all took less than 20 min. to travel from the compound to Cranberry Lake. Speeds and fuel consumptions on this route are considerd to reflect accurately performance on mineral terrain as no serious delays were occasioned by stoppages, and times are indicative only of the caution with which drivers proceeded.

Draw-Bar Pull Tests

Two methods of measuring draw-bar pull were used simultaneously.

The graphs in Figs. 53 to 55 show the variation in draw-bar pull expressed as a percentage of the vehicle test weight versus percentage slip of the wheels or tracks. They were plotted from data obtained by the Waterways Experiment Station team, as shown in Table 7.

All runs were carried out on FI-FIE cover. The Water Buffalo was used as a loading vehicle for the heavier vehicles, and a Weasel was used to load or "pull-down" the lighter vehicles such as the RN10. The draw-bar pull was measured with a load cell hooked to the end of the towing cable, and was recorded simultaneously with measurements of vehicle slip, i.e., speed obtained from a fifth wheel, and wheel or track speed obtained from a pulse generator (Fig. 50).

Draw-bar pull data were also obtained by OATRU staff. Two strain-gauge load cells were manufactured with the following ratios: 0 to 6,000 lb.; 6,000 to 12,000 lb.

An Ellis Associates Bridge Amplifier and Meter (BAM-1) was used to balance the strain-gauge bridges, and the load cells were accuratly calibrated on a Tinius Olsen Testing Machine. The method of calibration and instrumentation allowed the load in pounds to be read directly from the BAM-1. A Sanborn single-channel recorder was connected to the output of the BAM-1 to give a continuous record of draw-bar pull in pounds.

It was assumed that this instrumentation would enable the maximum or representative draw-bar pull to be determined from the record, and this was corroborated by the tests. It was also possible to make a good determination of the draw-bar pull by taking a record directly from the BAM-1 meter alone. The maximum or representative draw-bar pull as recorded by OATRU is shown by a black bar on the ordinate of the graphs in Figs. 53 to 55, and the data in Table 8.

PRESSURE CELL RECORDINGS

Introduction

Soil pressure measurements were taken during the field trials to determine the intensity and distribution of pressures within the soil, as the vehicles traveled over the muskeg. The purpose of the research was to investigate the mechanics of failure within the soil that cause a vehicle to become immobilized.

As many characteristics vary from vehicle to vehicle, only typical soil pressure measurements were recorded; but these were judged to be most significant to soil mechanics.

Instrumentation

Measurements were made by means of 4-in. diameter pressure cells connected to a Bridge-Amplifier-Meter and a Sanborn Recorder (Figs. 51 and 56). The aluminum pressure cells had pressure-sensitive diaphragms fitted with four SR-4 strain-gauges (Figs. 52 and 56). An orientation was chosen so that the gauges were self-compensating for temperature effects. The calibration of the cells was linear over the range of application; two cells were made to cover the ranges of 0 and 0 to 20 lb./1 sq. in. (Fig. 57).

Field Measurements

All tests were conducted in peat with cover type FI-FIE. The cells were inserted below the muskeg mat, on the center-line of one of the tracks of the vehicle.

Pressures recorded in the peat as the vehicles passed over the cells are shown as follows:

Fig. 58 — XM571	Fig. 62. — Jeep
Fig. 59 — Nodwell RN10	Fig. 63. — Tree Farmer
Fig. 60 — tracked Land Rover	Fig. 64. — Iron Mule
Fig. 61 — Volvo	Fig. 65. — Timberjack

It was noted in subsequent tests that the effect of draw-bar pull generally did not change, significantly the vertical pressures. However, the effect of draw-bar pull was measured for some vehicles, and depended on the location of the hitch; the effect of draw-bar pull in influencing vertical pressures was a transfer of load from one axle to another.

The advantage of tracks over wheels, as shown by the graphs, is that the soil pressure is gradually increased and diminished. The "approach-angle" has merit in this respect as well as for climbing obstructions. In the tracked Land Rover, the approach-angle is similar to that of a wheel; also the pressure drops almost to zero between the wheels of a bogie. This shows that the track tension is not sufficient to distribute the load, and the use of the track is merely to rotate the wheels.

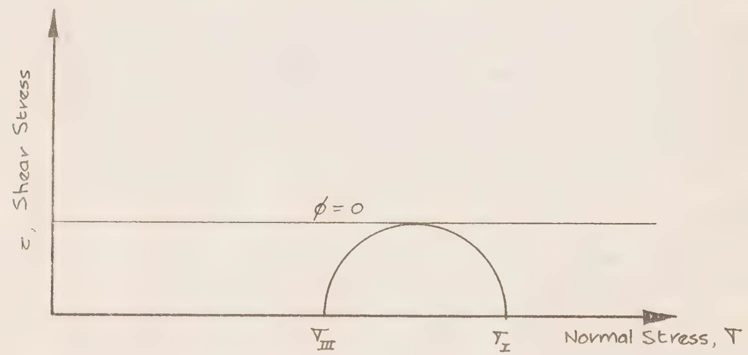
Significance of Pressure Distribution in Soils

For dynamic (i.e., short-term) loading, the chief considerations are the intensity and distribution of pressures. Loss of strength in soil occurs during remolding and, as the strains in soil are due to stress differences, these stress differences should be minimized.

The foundation soil is examined rather than the mat, because it is the loss of strength of the foundation soil that causes immobilization of the vehicle. The mat adds to the strength of the peat by spreading the load and by keeping in place peat adjacent to the loaded zone. It is important to reduce damage to the mat as much as possible by elimination, in vehicle design, of sharp shoulders on track grousers and rubber tires.

According to soil mechanics theory, the maximum stress that a soil can carry depends on the confining stress around the soil, i.e., the stress that prevents lateral movement of soil from under the applied stress. This condition applies to dynamic loading, in which consolidation does not take place.

As the shear strength of a soil is equal to half the difference between the maximum principal stresses, it can be seen that the major principal stress can be increased if the minor principal stress is increased to the same extent. Mohr's Diagram shown below is a graphical representation of the stress conditions.



$$\tau = \tfrac{1}{2}(\sigma_{I} - \sigma_{III})$$

where τ = Shear Stress

σ_{I} = Major Principal Stress

σ_{III} = Minor Principal Stress

For example, if the shear strength of peat is 1/2 lb./sq. in., it is possible to apply a major principal stress of 10 lb./sq. in. when a minor principal stress of 9 lb./sq. in. is applied. On the same peat, it is possible to apply a major principal stress of 100 lb./sq. in. when a minor principal stress of 99 lb./sq. in. is applied. If the applied stresses are gradually increased and diminished, the maximum stresses can be greater than the shear strength of the soil.

Application to Vehicle Performance

It appears from the field measurements that gradual increase and decrease of applied stresses should be the aim of vehicle designers. It is on this principle that tracked vehicles, and more recently the large rubber-tired vehicles, depend for mobility. Equally as important as the pressure distribution along the track is the distribution laterally, i.e., the lateral flexibility of the track or tire. This lateral distribution is significant both from the aspect of spreading the load and avoiding zones of high shear that cause damage to the mat.

TABLE 1

Average Subsidence

VEHICLE	FI(E) Pass No.	FI(E) Subsidence (ft.)	EI Pass No.	EI Subsidence (ft.)	DI Pass No.	DI Subsidence (ft.)
XM571	40	0.56	46	1.06	40	0.69
RN10	40	0.38	50	0.29	40	0.26
Tracked Land Rover	40	0.48	50	0.98	40	2.0
Jeep	16	0.76	40	0.40	8	0
Volvo	27	0.44	40	0.37	40	0.3
Tree Farmer	38	0.77	10	0.90	30	1.59
Timberjack	15	1.10	12	1.0	-	-
Iron Mule	3	0.35	5	1.6	3	-
Jiger	50	0	-	-	-	-
Rat	50	0	-	-	-	-
Hovertruck	26	1.0	-	-	-	-
Airoll	50	1.5	-	-	-	-

TABLE 3

Vehicle Speeds — Organic Terrain — FI(E)

VEHICLE	Time for 100 ft. (sec.)	Maximum Speed (m.p.h.)	Time for 100 ft. - Standing Start (sec.)	Average Speed (m.p.h.)	Turning Radius (ft.)
XM571	4.75	14.6	9.2	7.4	27
RN10	9.5	7.2	10.2	6.7	23
Tracked Land Rover	7.5	9.1	9.2	7.4	37
Jeep	5.85	11.6	7.0	9.8	20
Volvo	5.55	12.3	7.1	9.6	18
Tree Farmer	8.2	8.5	11.4	6.0	22
Timberjack	9.6	7.1	14.6	4.7	-
Iron Mule	-	-	-	-	-
Jiger	5.15	13.2	7.0	9.8	0
Rat	4.8	14.2	8.2	8.3	6

TABLE 2

Cone Penetrometer 'Indices

Depth in.	FI(E) Before traffic 0-6	6-12	12-18	FI(E) Pass No.	FI(E) After traffic 0-6	6-12	12-18	EI Before traffic 0-6	6-12	12-18	EI Pass No.	EI After traffic 0-6	6-12	12-18	DI Before traffic 0-6	6-12	12-18	DI Pass No.	DI After traffic 0-6	6-12	12-18
VEHICLE																					
XM571	32	49	65	40	79	60	69	30	35	51	46	20	31	40	28	41	54	40	44	53	75
RN10	30	42	53	40	78	64	75	31	41	55	50	37	47	54	27	44	56	40	30	43	67
Tracked Land Rover	25	40	56	40	66	59	75	44	54	62	20	66	56	63	38	58	75	-	-	-	-
Jeep	32	48	67	14	37	39	53	38	62	158	40	97	139	269	59	89	196	-	-	-	-
Volvo	27	39	59	18	9	20	29	35	58	114	40	93	95	235	40	70	205	40	95	177	284
Tree Farmer	36	53	67	20	71	54	72	41	56	60	10	36	40	55	36	56	75	-	-	-	-
Timberjack	29	40	58	-	-	-	-	43	49	58	-	-	-	-	-	-	-	-	-	-	-
Iron Mule	32	46	60	-	-	-	-	41	50	66	-	-	-	-	34	49	75	-	-	-	-
Jiger	37	46	56	-	37	47	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rat	35	42	56	-	37	39	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Airoll	34	42	46	50	39	36	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hovertruck	39	56	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 4

Vehicle Speeds — Water

VEHICLE	WITHOUT AUXILIARY PROPULSION Time for 100 ft. (sec.)	Speed (m.p.h.)	Turning Radius (ft.)	WITH AUXILIARY PROPULSION Time for 100 ft. (sec.)	Speed (m.p.h.)	Turning Radius (ft.)
XM571	52.5	1.3	12 to 15	-	-	-
RN10	88.0	0.8	Variable	54.7	1.25	0
Jiger	68.5	1.0	-	23.5	2.9	0
Rat	31.4	2.2	10 to 12	-	-	-
Airoll	-	Approx. 2 to 3	5 to 10	-	-	-

TABLE 5

Speed and Fuel Consumption — Dinner Lake Circuits

Amphibious Route Distance 6900 ft.
Non-amphibious Route Distance 7900 ft.

VEHICLE	Time (hr. : min.)	Speed (m.p.h.)	Fuel (gal.)	Consumption (m.p.g.)
XM571	1:19	0.99	2.51	0.52
RN10	1:21	0.97	-	-
Tracked Land Rover	Incomplete	-	-	-
Jeep	1:00	1.50	0.88	1.70
Volvo	1:06	1.36	0.50	2.99
Tree Farmer	0:11	8.16	1.28	1.17
Timberjack	0:16	5.61	1.68	0.89
Iron Mule	0:21	4.27	0.60	2.49
Jiger	0:09	8.71	-	-
Rat	0:50	1.56	1.32	0.99

TABLE 6

Speed and Fuel Consumption — Compound to Cranberry Lake

Distance = 9176 ft.

VEHICLE	Time (min.)	Speed (m.p.h.)	Fuel (gal.)	Consumption (m.p.g.)
XM571	13	8.01	1.69	1.03
RN10	41	2.54	0.23	7.56
Tracked Land Rover	-	-	0.57	3.05
Jeep	-	-	0.82	2.12
Volvo	-	-	0.64	2.72
Tree Farmer	20	5.21	0.21	8.28
Timberjack	17	6.14	0.48	3.62
Iron Mule	20	5.21	0.23	7.56
Jiger	8	13.03	0.12	14.48
Rat	20	5.21	0.41	4.24

TABLE 7

Draw-Bar Pull (DBP) Data (Waterways Expt. Stn.)

	Test No.	Pass No.	DBP lb.	Percentage slip	Percentage of Test Wt.
DYNATRAC XM571 Test Weight 7400 lb.					
	1	1	5200	34	70
		1	5400	35	73
		1	4000	68	54
		2	3000	10	40
		2	2400	6	32
		3	5600	24	76
		3	6000	25	81
	2	1	4000	15	54
		1	2000	6	27
		1	3200	10	43
		2	5400	25	73
		3	5600	37	76
		3	5400	52	73
		3	5600	47	76
	3	1	5600	26	76
		1	4000	13	54
		2	3200	9	43
		2	3800	11	51
			1300	Rolling resistance	
		3	6000	27	81
		3	4800	71	65
NODWELL RN10 Test Weight 3500 lb.					
	4	1	1400	5	40
		2	2000	5	57
		3	1600	4	46
		4	2000	3	57
			650	Rolling resistance	
		5	2500	10	71
		6	2600	9	74
		7	1000	4	29
		8	2500	10	71
Vehicle capability limited. Vehicle did not have enough available power for its track system.					
VOLVO Test Weight 4630 lb.					
	5	1	1800	25	39
		2	2000	20	43
		3	1800	37	39
		4	1600	21	35
		5	1900	40	41
		6	1800	35	39
		7	1300	10	28
		8	2000	24	43
		9	1700	20	37
			1000	Rolling resistance	

	Test No.	Pass No.	DBP lb.	Percentage slip	Percentage of Test Wt.
	6	1	2050	30	44
		2	1300	10	28
		3	1800	100	39
		4	1500	100	32
JEEP M38A1 Test Weight 3465 lb.					
	7	1	900	24	25
		2	550	15	15
		3	400	12	11
		4	700	18	19
		5	750	16	21
		6	900	21	25
		7	600	12	17
		8	700	37	19
		9	500	12	14
		10	450	10	12
		11	300	6	8
			800	Rolling resistance	
		12	900	33	25
TRACKED LAND ROVER Test Weight 7350 lb.					
	8	1	3000	10	41
		2	3000	1	41
		3	3000	0	41
		4	2800	2	38
		5	2800	4	38
			1600	Rolling resistance	
	9	1	3100	6	42
		2	3200	10	44
		3	3400	10	46
Vehicle capability limited. Vehicle did not have enough available power for its track system.					
TREE FARMER Test Weight 14,000 lb.					
	10	1	4800	12	34
		2	2000	6	14
		3	7800	25	56
		4	9200	31	66
		5	7200	53	51
		6	9200	27	66
		7	4600	13	33
		8	1200	1	9
		9	6000	63	43
			8400	36	60
			5200	13	37
			8400	56	60
			1200	1	9
			4400	9	31
			8400	25	60
			8000	30	57

	Test No.	Pass No.	DBP lb.	Percentage slip	Percentage of Test Wt.
	10		8400	49	60
	(cont.)		8800	49	63
			2400	Rolling resistance	
			7800	25	56
TIMBERJACK					
Test Weight 16,000 lb.					
	12	1	6000	12	38
		2	8000	29	50
		3	5800	58	36
		4	4000	9	25
		5	7000	33	44
		6	5200	53	32
		7	8200	33	51
		8	6400	53	40
	13	1	3800	5	24
		2	6000	19	38
		3	5600	53	35
		4	6000	16	38
		5	6000	48	38
		6	7200	41	45
		7	8000	38	50
		8	7200	31	45
			2800	Rolling resistance	
IRON MULE					
Test Weight 12,500 lb.					
	14	1	6000	25	48
		2	5000	20	40
		3	6400	30	51
		4	5600	50	45
		5	1200	6	10
		6	5000	50	40
		7	6000	27	48
		8	2400	8	19
		9	6400	37	51
	15	1	2400	7	19
		2	1600	9	13
		3	5600	37	45
		4	2400	9	19
		5	5200	43	42
		6	6400	40	51
		7	6000	44	48
		8	6000	40	48
		9	5400	61	43
			2400	Rolling resistance	
AIROLL LVAX1					
Test Weight 5900 lb.					
	16	1	*2700#	-	-
		2	2800#	-	-

* This was an anchored maximum pull.

2800# is the maximum that the vehicle's torque convertor would let it pull. This is not the maximum capability of the track system.

	Test No.	Pass No.	DBP lb.	Percentage slip	Percentage of Test Wt.
TRACKED LAND ROVER Test Weight 5000 lb.					
	17	1	1750	20	35
		2	1800	22	36
		3	1800	20	36
		4	1200	13	24
		5	1700	32	34
		6	800	11	16
		7	1000	10	20
		8	1400	11	28
		9	1300	11	26
		10	1700	34	34
		11	1600	16	32
		12	1400	14	28
		13	1300	15	26
		14	1000	10	20
			900	Rolling resistance	
	18	1	1100	11	22
		2	1200	11	24
		3	900	12	18
		4	1400	35	28
		5	1700	27	34
		6	700	9	14
		7	1450	22	29
		8	1700	24	34
		9	1200	16	24
		10	1600	30	32
		11	1350	19	27
		12	1600	24	32
		13	1250	15	25
		14	1400	17	28
		15	1500	30	30
		16	1000	69	20
			850	Rolling resistance	
RAT Test Weight 2475 lb.					
	19	1	1400	6	57
		2	1800	9	73
		3	1800	7	73
		4	700	0	28
			500	Rolling resistance	
		5	2000	9	81
		6	1900	12	77
		7	1100	5	44
		8	1500	5	61
		9	400	0	16
		10	800	0	32

Vehicle capability limited. Vehicle did not have enough available power for its track system.

TABLE 8

Draw-bar Pull Data (OATRU)

VEHICLE	Gross weight (lb.)	Payload (lb.)	Max. steady draw-bar pull (lb.)	Pull as percentage of test weight	Tow-back pull (lb.)	REMARKS
Canadair XM 571	Front - 3905 Rear - 3365 Total - 7270	Front - 500 Rear - 1500 Total - 2000	6250	82	1100	Eleven runs completed First gear — low range. 6500 lb. was maintained for very short periods.
Nodwell RN10	3600	1000	2500	70	1000	Four runs completed.
Volvo	4570	1000	1500	32	1100	Four runs completed. four-wheel drive — First gear — low range. Peaks of 2000 lb. held for short periods, but high slippage occurred at 1500 lb.
Jeep	3465	2840	1000	29	950	One run completed. Four-wheel drive — First gear — low range. High slippage occurred at 1000 lb. Vehicle sank 1 ft.
Land Rover	8250	750	3500	42	1700	Four runs completed. First gear — low range. 4000 lb. maintained for very short periods.
Tree Farmer	14,010	4000	9400	68	2500	Three runs completed. First gear — low range. 9800 was maintained for a short period with some slippage.
Timberjack	16,000	4000	9400	59	3750	Two long runs completed. First gear — low range 10,000 lb. maintained for short periods. Pull was variable; 9400 lb. may be too high.
Iron Mule	12,450	1000	6250	50	3750	Two long runs completed. First gear — low range. 6900 lb. was maintained for very short periods.

APPENDIX 1

Plan of Tests

Organic Terrain

Where practicable, the following tests were completed by each vehicle in each of the four categories of organic terrain — FI(E), EI, DI, AEI-ADE.

(a) Number of passes to immobilization in a 100-ft. test lane, with cone penetrometer and subsidence measurements at 0, 10, 20, and 40 passes. If immobilization did not occur, tests were usually ended after the 40th pass.

Observers noted aspects of vehicle performance and terrain response that contributed to, or were detrimental to, mobility according to criteria established by OATRU.

(b) Maximum speed with full specified payload or maximum speed for vehicle with load reduced to make it mobile. Vehicle was clocked over a measured and staked 100-ft. course. Maximum speed criterion was driver safety or available power.

(c) Minimum turning radius at the end of the maximum speed run.

(d) Minimum turning radius in a figure-of-eight course with test continued to immobilization, and with penetrometer and subsidence measurements at 1, 10, 20 and 40 passes. If immobilization did not occur, tests were ended after the 40th pass.

(e) Acceleration tests. Minimum time required to go 100 ft. from a standing start.

Water Areas

A water course 100 ft. long was set up, with water deeper than wading depth. Ends were marked by two lines on shore; full specified payload was carried. Tests were:

(a) Check on buoyancy and steerability of vehicles by a run out from shore and back.

(b) Maximum speed with auxiliary equipment operating. Vehicles were clocked over the course once in each direction, so that wind and current effects could be evaluated.

(c) Maximum speed without auxiliary equipment operating. Test as above.

(d) Vehicles were tested for maneuverability and seaworthiness in maximum wind and wave conditions. Included measurement of minimum turning radius.

Inorganic Terrain

(a) Speed tests. The route to Cranberry Lake comprised typical inorganic terrain of the test area — granite outcrop and bush — and vehicles were required to pass over it with full specified payload, and at maximum speed consistent with driver safety and avoidance of vehicle damage.

(b) Maneuverability and obstacle course. The same course included several natural obstacles that had to be avoided or negotiated, and vehicles were required to attempt as many as possible, with regard for driver safety and vehicle damage.

Cross-Country Course

The course around Dinner Lake used previously was again used for cross-country tests. Those vehicles without amphibious capabilities negotiated an alternative course that closely paralleled the above, but contained no sections that were not fordable.

Full specified payload was carried.

Point-to-Point Courses

It was intended to establish a triangular course in the vicinity of Dinner Lake to include 3 mi. of organic and associated terrain over which drivers had to choose their own routes, but time did not allow this, and a second circuit of Dinner Lake was substituted in some cases.

Ad Hoc Tests

If a particular aspect of mobility seemed worthy of extra study, it was examined during those periods in the program that were reserved for this purpose.

Records

Cone penetrometer and subsidence records were obtained prior to, and during, vehicle tests so that the response of the terrain could be ascertained.

Fuel consumption, time, and distance measurements were obtained at every convenient opportunity.

Evaluation of performance and design features of each vehicle were made after collation of field observers' data obtained according to criteria established by OATRU.

When feasible, drawbar pull and pressure cell measurements were made by the OATRU group, and members of the W.E.S. group obtained drawbar pull *vs.* slip measurements.

SUMMARY OF PROGRAM OF TESTS

DAY	MORNING	AFTERNOON
Sunday, Aug. 16		Meeting in Parry Sound.
Monday, Aug. 17	RN10 — XM571 — Gama Goat and Marsh Screw tests in EI.	RN10 — XM571 — Gama Goat and Marsh Screw tests in FI.
Tuesday, Aug. 18	RN10 — XM571 — Gama Goat and Marsh Screw water trials.	RN10 — XM571 — Gama Goat and Marsh Screw tests in D & A cover.
Wednesday, Aug. 19	RN10 — XM571 — Gama Goat and Marsh Screw tests in A cover.	Further evaluation of this group.
Thrusday, Aug. 20	Jeep, Land Rovers, Volvo and Hovertruck tests in EI.	Jeep, Land Rovers, Volvo and Hovertruck tests in FI & D cover.
Friday, Aug. 21	Jeep, Land Rovers, Volvo and Hovertruck tests in D & A cover.	Further evaluation of this group.
Saturday, Aug. 22	Vehicle maintenance.	
Monday, Aug. 24	Timberjack, Tree Farmer and Iron Mule tests in EI.	Timberjack, Tree Farmer and Iron Mule in FI & D cover.
Tuesday, Aug. 25	Timberjack, Tree Farmer and Iron Mule tests in D & A cover.	Further evaluation of this group.
Wednesday, Aug. 26	Jiger and Rat tests in EI & FI.	Jiger and Rat tests in water, D & A cover.
Thursday, Aug. 27	Jiger and Rat tests in A cover. Other vehicles move to Dinner Lake.	All vehicles at Dinner Lake. Circuits by Jiger and Rat.
Friday, Aug. 28	Circuits of Dinner Lake by all vehicles. Circuits to travel point-to-point course.	Vehicles completing.
Saturday, Aug. 29	Completion of outstanding tests. Vehicle departures.	

GEMINI PHASE

Thursday, August 27

9:30 a.m.	Commence water trials.
	Test 1 — floating characteristics and waterproofing.
	2 — wheel propulsion in water.
	3 — wheel propulsion plus lift.
	4 — wheel propulsion plus lift plus thrust.
17:00	End of work day.

Friday, August 28

8:30 a.m.	Complete water trials.
17:00	End of work day.

Saturday, August 29

8:30 a.m.	Assemble at water test site.
9:00	Move vehicle to area 10G.
12:30	End of work day.

Monday, August 31

8:30 a.m.	Hovertruck to be at site entrance.
9:00	Commence testing in FEI with Gemini and Hovertruck in adjacent lanes to obtain initial data on the comparison of the use of the air cushion assist principle.
16:30	Return Hovertruck to parking area or Macklaim's yard.
17:00	End of work day.

Tuesday, September 1

8:30 a.m.	Site entrance.
9:00	Continue and complete testing of Gemini and Hovertruck.
14:00	Move Gemini to site entrance for loading. Return Hovertruck to Macklaim's.
17:00	End of work day.

APPENDIX 2

Vehicle Data

XM571 Carrier, utility, articulated

SPECIFICATIONS

General

Gross weight:	Unit 1	3905 lb.		Unit 2	3366 lb.
Curb weight:		3005 lb.			1866 lb.
Payload:		500 lb. plus 2 persons			1500 lb.
Total length:	234 in.	Width: 64 1/2 in.	Height: 72 in.		
Belly clearance:	12 in.	Width: 24 in.			
Ground pressure:	2.09 p.s.i. front; 1.80 p.s.i. rear; 1.94 p.s.i. mean				
Center of gravity:	Unit 1 25.1 in. above ground				
	Unit 2 19.7 in. above ground				
Gradability:	60 per cent				
Tipping angle:	40°				

Drive train

Engine:	Chevrolet Corvair aircooled flat six
Max. brake hp.:	70 at 3600 r.p.m.
Fuel capacity:	25 + 34 (rear tank) US gal.
Octane rating:	Standard gasoline

Power train

Clutch:	Dry disc, 8 in. heavy duty G.M.
Transmission:	Four forward constant mesh gearbox with one reverse, G.M. standard type
Speed ratios:	Forward 4 x 2
	Reverse 1 x 2
Final reduction:	G.M. auxiliary 2-speed dropbox

Running gear

Tracks:	(band with center-drive guide) Rear drive
Length:	111 1/2 + 127 1/2 in. Width: 18 in.
Wheels:	8-14 in. dia.

Steering

Hydraulic system giving rotary servo control and sensory direction.
Front unit only: Clutch-brake system

Suspension

Torsion bars with trailing arms and shock absorbers

Hull

Aluminum fully amphibious
Freeboard: 8 in. fully loaded
Approach angle: 80° min.
Departure angle: 60° min.
Front of vehicle to front axle: 28 in.
Rear of vehicle to rear axle: 28 in.

Nodwell RN10

SPECIFICATIONS

General

Gross weight:	3600 lb.
Curb weight:	2600 lb.
Payload:	1000 lb.
Total length:	125 in. Width: 78 in. Height: 57 in.
Belly clearance:	8 in. Width: 14 in.
Ground pressure:	Unloaded 0.72 p.s.i. Loaded 1.03 p.s.i.
Gradability:	60 per cent

Drive train

Engine:	Ford 122E four in-line O.H.V. water-cooled
Max. brake hp.:	62 at 3900 r.p.m.
Fuel capacity:	10 Imp. gal.

Power train

Clutch:	Ford single dry disc, 8 in.
Transmission:	Ford 4 speed synchromesh
Differential:	Nodwell No. 4 planetary steering

Running gear

Tracks:	Rubber and steel
Length:	96 in. Width: 24 in.
Wheels:	6-400x15
Auxiliary water propulsion:	5 1/2 hp. outboard motor

Steering

Controlled differential

Suspension

Double transverse leaf

Hull

Fiberglass
Freeboard: 12 in.

Tracked Land Rover

SPECIFICATIONS

General

Gross weight:	8500 lb.
Curb weight:	7500 lb.
Payload:	1000 lb.
Total length:	156 in. Width: 108 in.
Ground pressure:	2.3 p.s.i.
Gradability:	45 per cent
Tipping angle:	45°

Drive train

Standard Land Rover

Power train

Standard Land Rover

Running gear

Tracks:	Cuthbertson 2-4 in. x 6 ply nylon/cotton rubber belts with steel track shoes. Four tracks.
Length:	Each unit 36 in. Width: 14 in.
Wheels:	16-350x19

Steering

Hydraulic power assisted

Suspension

Lengthwise leaf springs

Jeep (M38A1 Cdn.) Truck, utility, 1/4 ton 4x4

SPECIFICATIONS

General

Gross weight:	3465 lb.
Curb weight:	2840 lb.
Payload:	625 lb.
Total length:	139 in. Width: 61 in. Height: 69 in.
Belly clearance:	8 in. Width: 42 in.
Gradability:	60 per cent
Tipping angle:	37°

Drive train

Engine:	Willy's model MD, water-cooled
Max. brake hp.:	59 at 3800 r.p.m.
Fuel capacity:	14.5 gal.
Octane rating:	standard gasoline

Power train

Clutch:	Single plate 8 in.
Transmission:	Warner synchromesh
Speed ratios:	Forward 3 x 2, reverse 1 x 2
Final reduction:	Transfer case, 2 speed

Running gear

Wheels:	4-700x16

Steering

Standard automative

Suspension

Lengthwise leaf springs (4 semi-elliptic)
Shock absorbers — 4

Volvo L3314N

SPECIFICATIONS

General

Gross weight:	4570 lb.
Curb weight:	3570 lb.
Payload:	1000 lb.
Total length:	159 in. Width: 64.8 in. Height: 70.5 in.
Belly clearance:	11 in. Width: 43 in.
Gradability:	60 per cent
Tipping angle:	34°

Drive train

Engine:	Volvo B18A, water-cooled
Max. brake hp.:	70 at 4500 r.p.m.
Fuel capacity:	11 Imp. gal.
Octance rating:	At least 93

Power train

Clutch:	Single dry plate 8 1/2 in., hydraulic
Transmission:	Volvo M40 gearbox fully synchronized
Speed ratios:	Forward 4 x 2, reverse 1 x 2
Final reduction:	Auxiliary hypoid gearbox, 2 speed, type ZF VA50
Differential:	Lock-up in the rear, standard front

Running gear

Wheels:	4-650x16, reverse tread on front wheels

Steering

Cam and roller, standard automotive

Suspension

Lengthwise leaf springs and rubber springs
4 shock absorbers

Tree Farmer carrier, model C5B, 4-wheel drive, center articulated

SPECIFICATIONS

General

Gross weight:	Front 7490 lb. Rear 6520 lb.
Curb weight:	Front 7490 lb. Rear 2520 lb.
Payload:	4000 lb.
Total length:	195 in. Width: 108 in. Height: 115 in.
Belly clearance:	26 in. Width: 60 in.
Gradability:	35 per cent
Tipping angle:	34°

Drive train

Engine:	G.M. 3-53, 3 cylinder, 2 cycle, water-cooled
Max. brake hp.:	93 at 2600 r.p.m.
Fuel capacity:	20 gal. Diesel

Power train

Clutch:	G.M. 12 in. heavy duty, single plate
Transmission:	Warner model T98A
Speed ratios:	Forward 4 x 2, reverse 4 x 2
Final reduction:	2
Differential:	No-spin lock-up front and rear

Running gear

Wheels:	4-23.1x26 traction sure-grip pressure 5 ± p.s.i.

Steering

Horizontal articulation

Suspension

None

Hull

Welded steel

Timberjack Model 230, wheeled skidder

SPECIFICATIONS

General

Gross weight:	16000 lb.
Curb weight:	12000 lb.
Payload:	4000 lb.
Total length:	198 in. Width: 104 in. Height: 95 1/2 in.
Belly clearance	22 in. Width: 45 in.
Gradability:	50 per cent

Drive train

Engine:	G.M. Diesel, water-cooled
Max. brake hp.:	97
Fuel capacity:	20 Imp. gal. Diesel

Power train

Clutch:	Single plate 12 in.
Transmission:	New process
Speed ratios:	Forward 4 x 2, reverse 1 x 2
Final reduction:	2 speed transfer gearbox
Differential:	No-spin front and back

Running gear

Wheels:	4-18.4x34 traction sure grip pressure 14 p.s.i.

Steering

Horizontal articulation

Suspension

None

Iron Mule

SPECIFICATIONS

General

Gross weight:	12450 lb.
Curb weight:	11450 lb.
Payload:	1000 lb. for test purposes
Total length:	240 in. Width: 86 in. Height: 108 in.
Belly clearance:	15 in. Width: 19 in.

Drive train

Engine:	Perkins Diesel, 3-A-152, 3 cylinder, water-cooled
Max. brake hp.:	Torque 117 ft./lb. at 1200 r.p.m.
Fuel capacity:	Diesel

Power train

Clutch:	Dry plate
Transmission:	3 speed gearbox
Speed ratios:	Forward 3 x 2, reverse 1 x 2
Final reduction:	2 speed planetary

Running gear

Wheels:	4-16.9x24 traction sure-grip pressure 19 to 20 p.s.i.

Steering

Horizontal articulation

Suspension

None

APPENDIX 3

Gemini Phase

Because of involvement in the main program, OATRU personnel were not able to participate in initial tests of the Gemini except as occasional observers.

Water Trials

The entry into Dinner Lake from the chosen sloping shore proved feasible and water trials commenced immediately. The wheels were able to propel the vehicle, and small deviations in course were possible when power was applied to wheels on one side only.

No records of speeds were obtained in early tests, but adjustment of depth of the wheels did not seem to produce any differences in speed.

When the air-cushion was applied, it was noted that air escaped more rapidly from the starboard side and produced an intermittent buffeting (approximately 120 per min.) with the vehicle listing to port at an angle of approximately 10° at the peak of each buffet.

Tests on FEI were conducted in 10G.

There was an inequality in the hydraulic pressure available to the wheel motors, and the vehicle veered to the right when traveling forward, and to the left when in reverse.

The air-cushion was operating for the first 16 passes, and large amounts of moss and sedge leaves accumulated on the engine radiator and air-cushion intake. Stops were made every 4 to 6 passes to clear away this material, and the radiator temperature indicator reached 235°F.

Tests were continued without the air-cushion in an attempt to break through the surface mat. In order to remain in the same ruts, it was necessary to attempt to steer the vehicle, but the application of all power to one set of front and rear wheels only resulted in overheating the power-take-off gear-box. Maximum temperature for this component has been established at 100°C, but has exceeded this in previous tests, usually reaching 100°C quite quickly and then taking about an hour's continuous running to reach 130°C or, unusually, 140°C. Under the unusual circumstances of the test on FEI, temperatures reached 150°C, and the test was halted to allow the gear-box to cool.

Wheels had been set initially to give a 9-in. ground clearance and had been altered periodically by 2-in. increments to give a 15-in. clearance on the 28th pass. Attempts to break through the mat were continued, and it was necessary to lower the wheels to provide a nominal 17-in. clearance by the end of the 55th pass. The ruts were not uniformly deep and there was some rolling in depressions. There was no immobilization at any time, although the vehicle had difficulty climbing out of shallow depressions in the ruts and the air-cushion was applied to effect 'recovery'.

The vehicle was moved to an adjacent area of FI where the surface water was 20 in. deep. The vehicle was able to proceed about 90 ft. into the area before striking a submerged obstruction.

Application of the air-cushion enabled it to back out and to resume forward travel. At a point 60 ft. from the shore, it was again unable to surmount an obstruction and, when power was increased in an attempt to recover the vehicle, two 0-rings on engine ports and center valve housing of the right front wheel failed, and hydraulic fluid was blown to a height of 15 ft.

The Gemini was recovered by the Water Buffalo.

Further tests were conducted in the same area after repairs had been made.

The vehicle moved forward and one wheel fell into a depression. Adjustments to wheel heights were made to level the vehicle, so that when the air-cushion was applied the vehicle rose in a balanced condition. However, the soft nature of the sub-surface peat and the number of other obstructions required that this procedure be continually repeated, and it became apparent that the hydraulic wheel motors were less than adequate for propulsion over small undulations, that the air-cushion power was also inadequate to lift the vehicle completely clear of obstructions, that the pattern of escape of air from beneath the vehicle was uncontrollable and that, under the circumstances, the effect of manual adjustment of wheel height could not be assessed.

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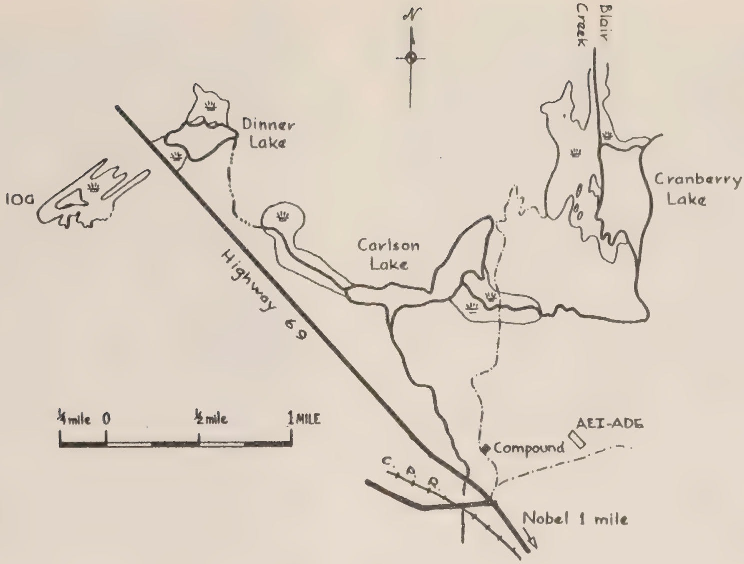


Fig. 1. Trials areas.

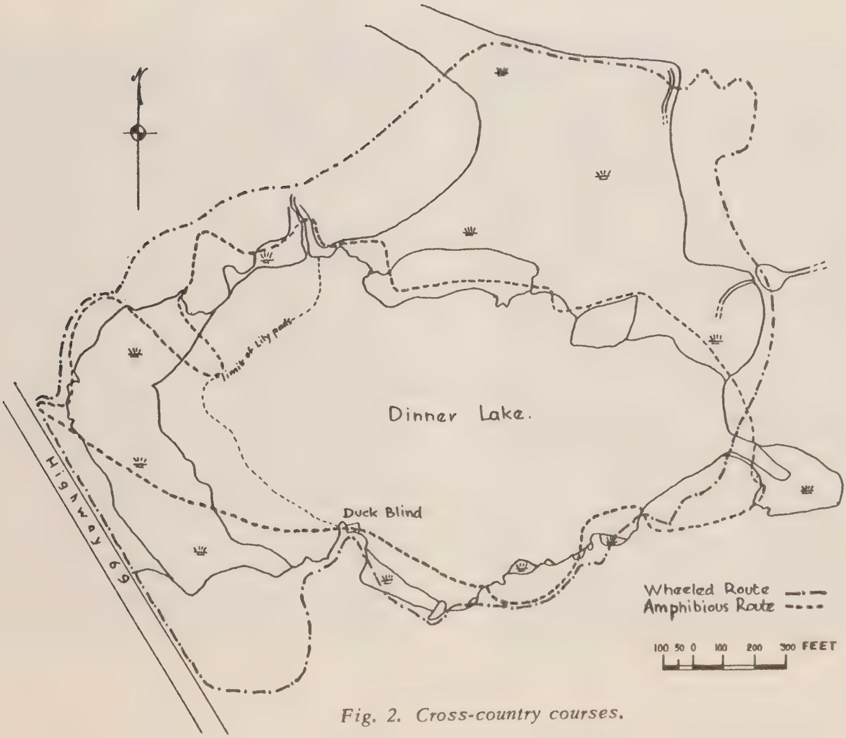


Fig. 2. Cross-country courses.

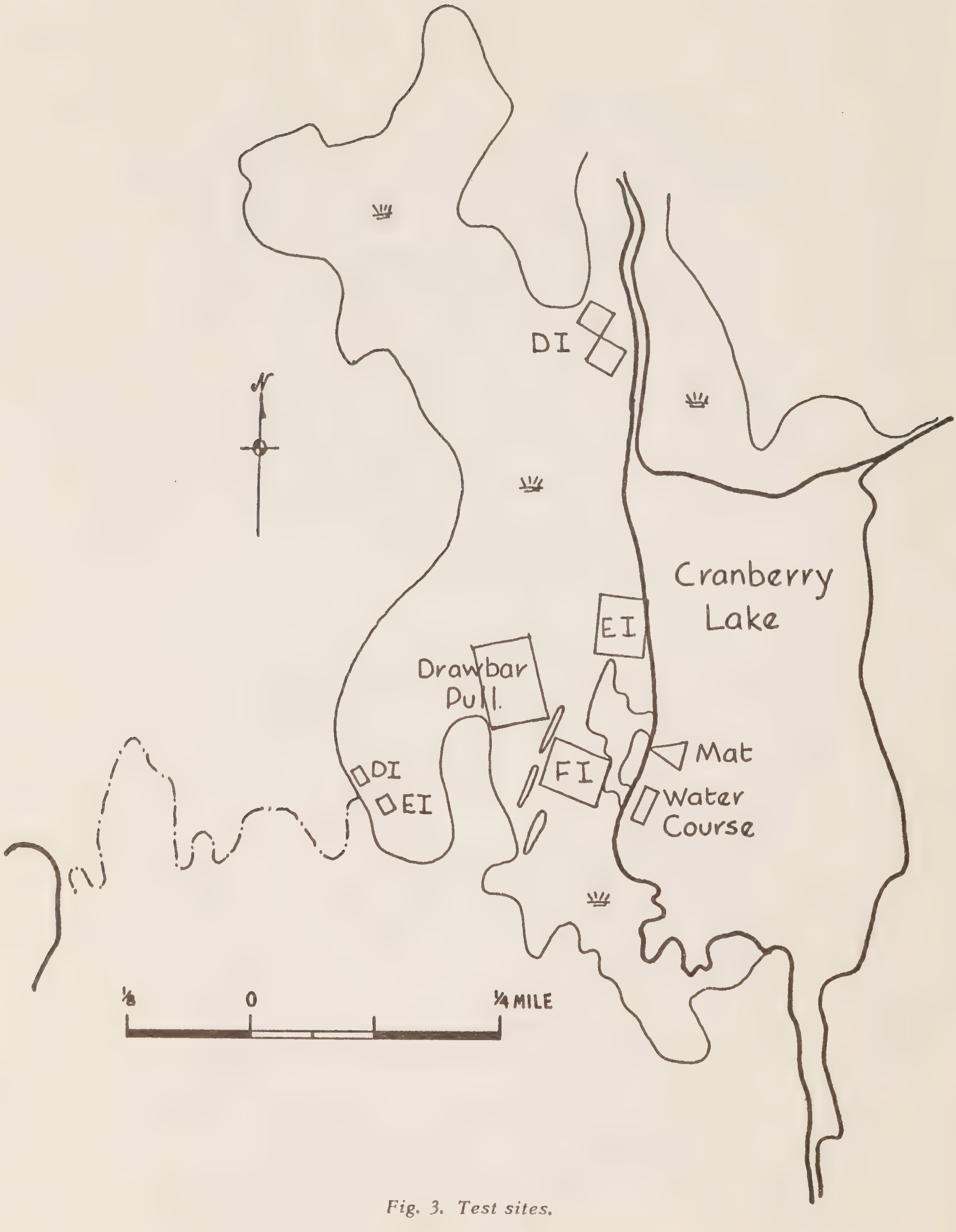


Fig. 3. Test sites.

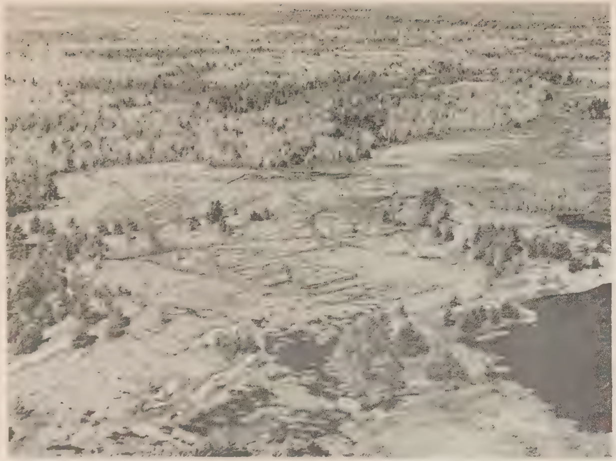


Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

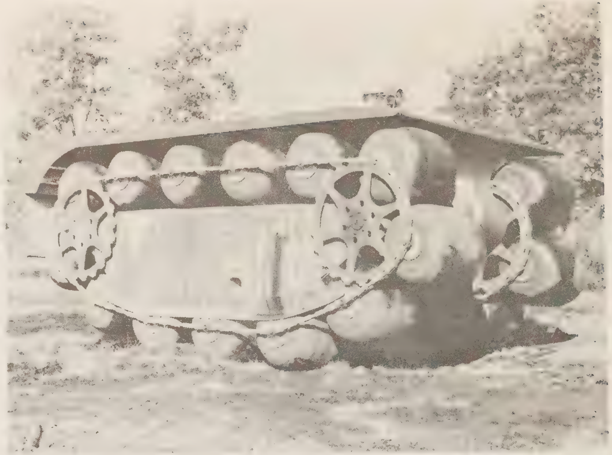


Fig. 17.

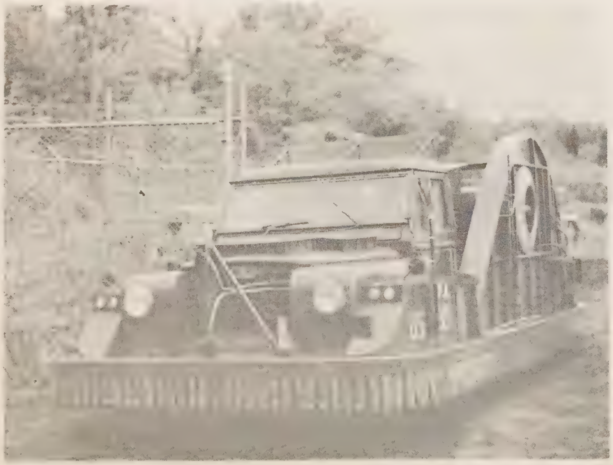


Fig. 18.

Fig. 19.

Fig. 20.

Fig. 21.

Fig. 22.

Fig. 23.

Fig. 24.

Fig. 25.

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

Fig. 30.

Fig. 31.

Fig. 32.

Fig. 33.

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

Fig. 38.

Fig. 39.

Fig. 40.

Fig. 41.

Fig. 42.

Fig. 43.

Fig. 44.

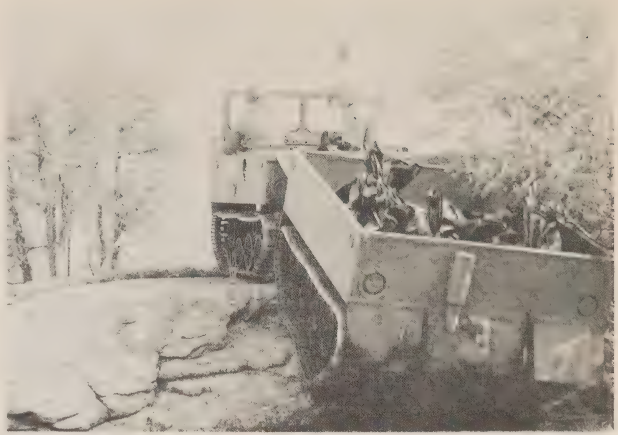


Fig. 45.

Fig. 46.

Fig. 47.

Fig. 48.

Fig. 49.

Fig. 50.

Fig. 51.

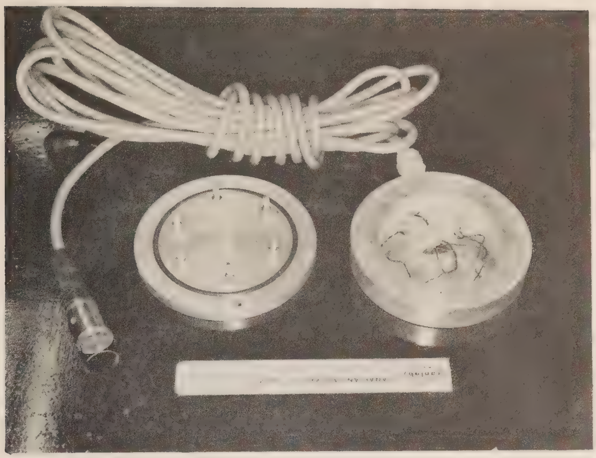
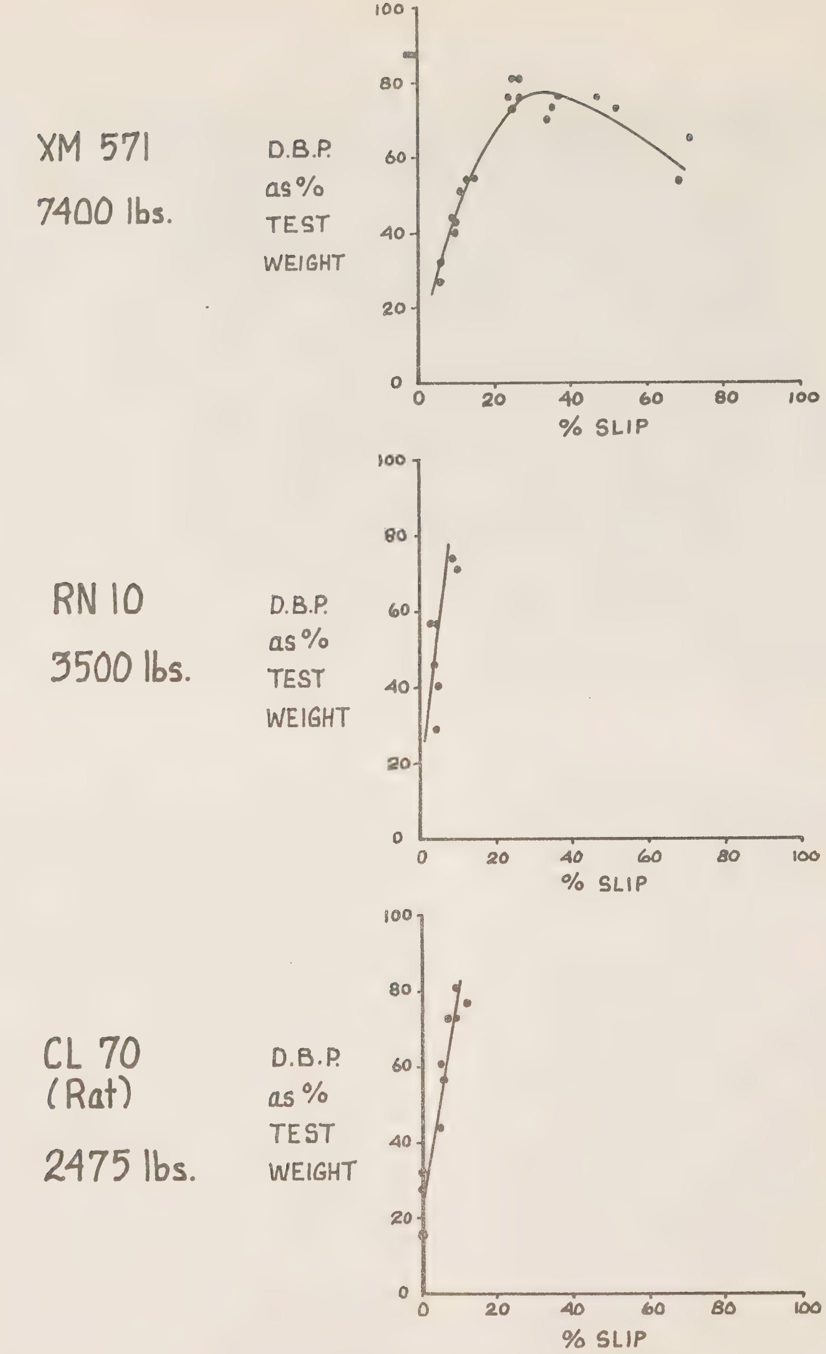
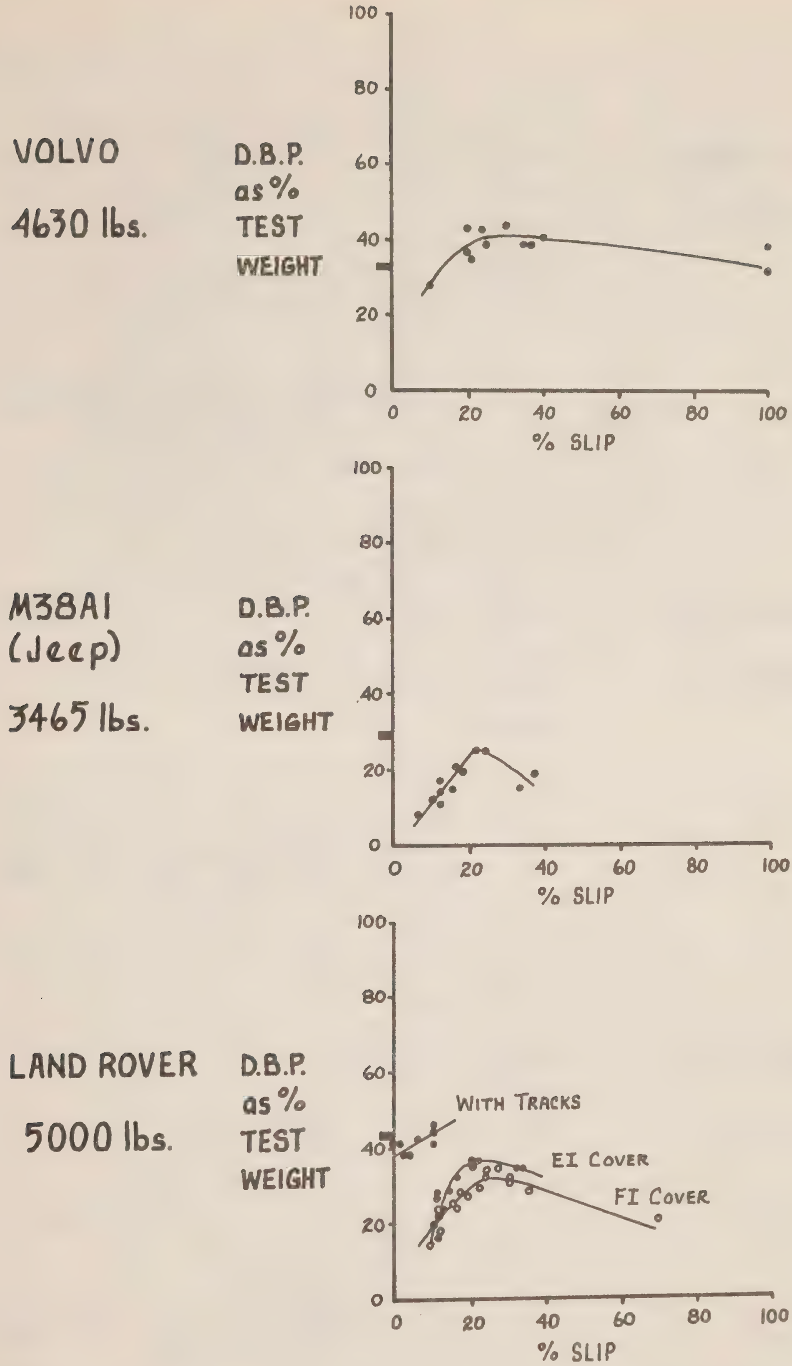


Fig. 52.



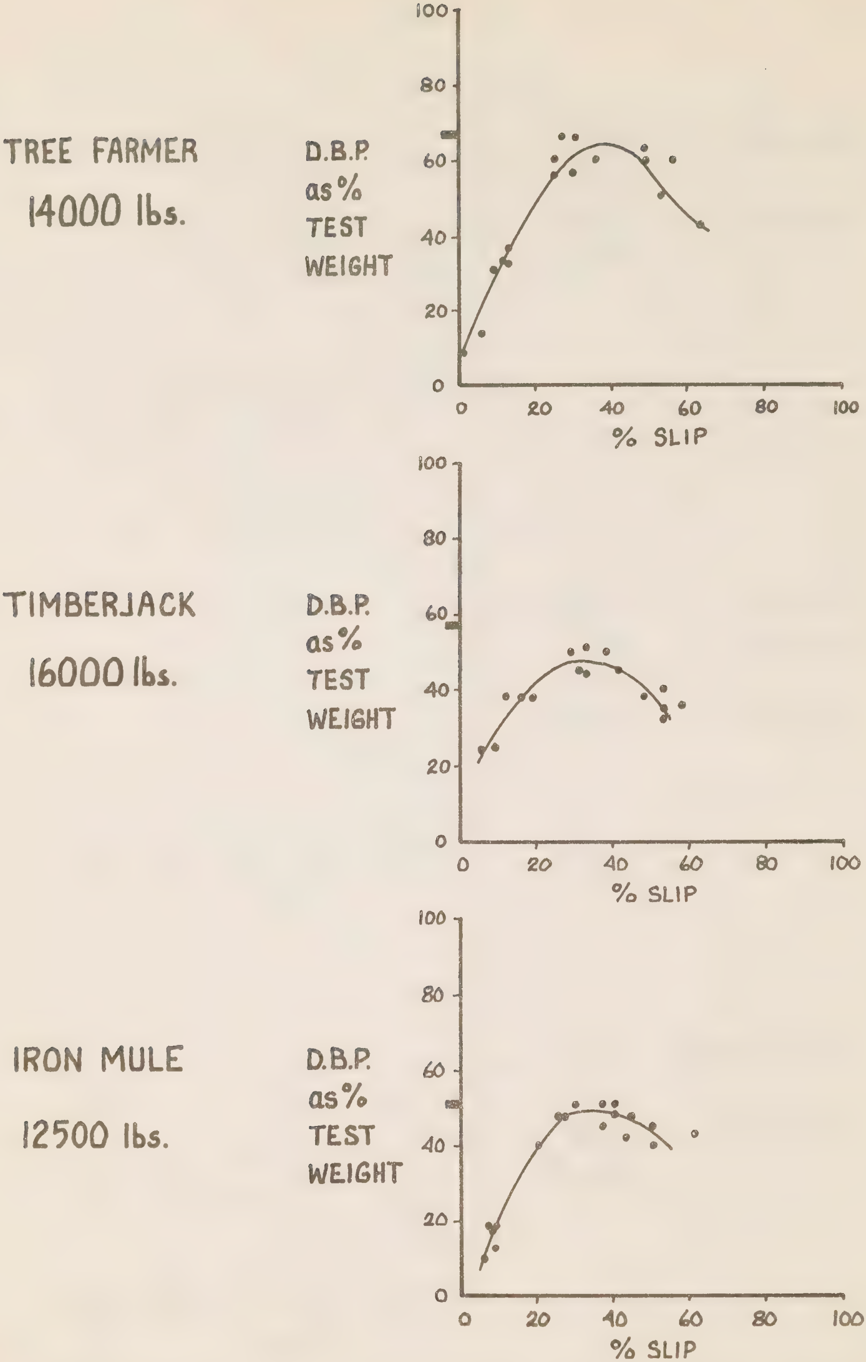
DRAWBAR PULL vs. SLIP: TRACKED VEHICLES

Fig. 53.



DRAWBAR PULL vs. SLIP: WHEELED VEHICLES

Fig. 54.



DRAWBAR PULL vs. SLIP : ARTICULATED WHEELED VEHICLES

Fig. 55.

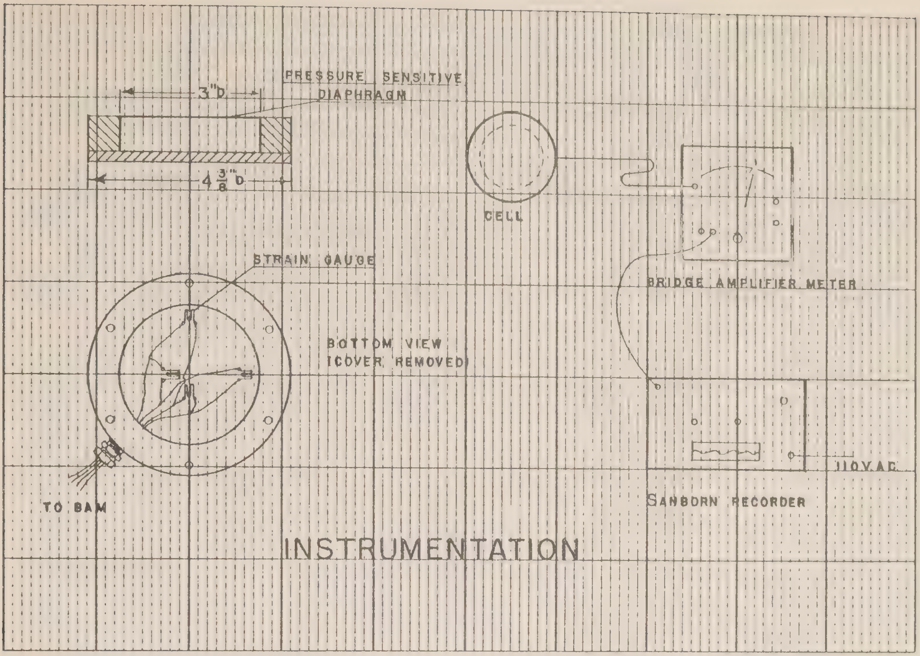

PRESSURE SENSITIVE
DIAPHRAGM
3"D
4 3/8"D
CELL
BRIDGE AMPLIFIER METER
STRAIN GAUGE
BOTTOM VIEW
(COVER REMOVED)
110 V.A.C.
SANBORN RECORDER
TO BAM
INSTRUMENTATION

Fig. 56.

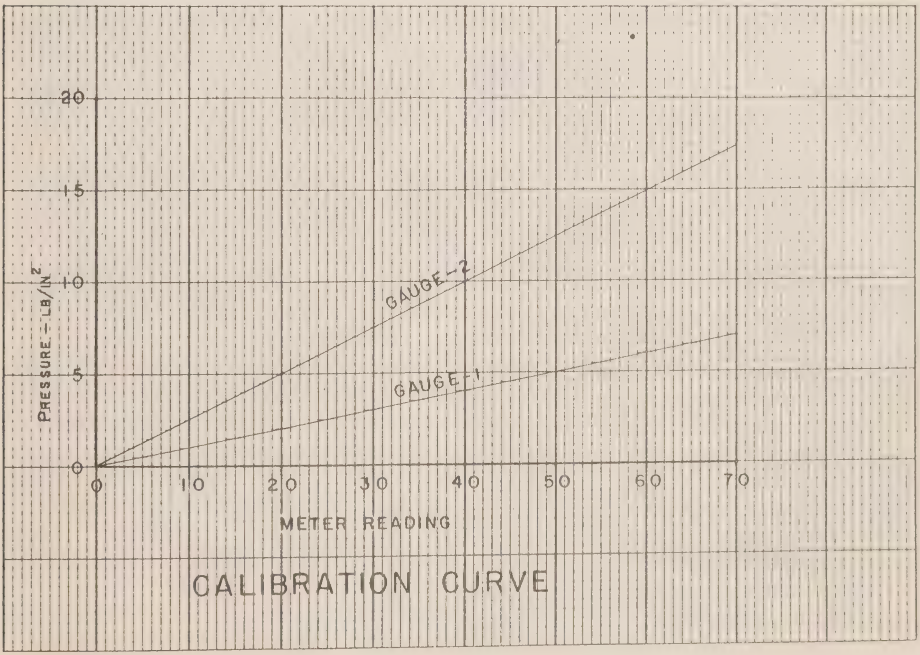

20
15
10
5
0
PRESSURE – LB/IN²
GAUGE – 2
GAUGE – 1
0
10
20
30
40
50
60
70
METER READING
CALIBRATION CURVE

Fig. 57.

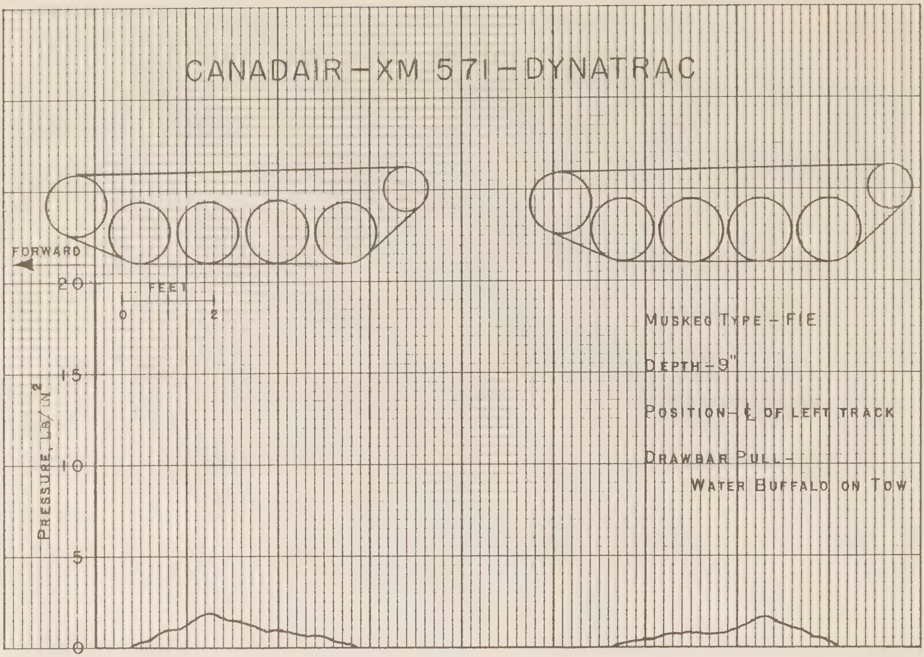

CANADAIR – XM 571 – DYNATRAC
FORWARD
FEET
0
2
MUSKEG TYPE – FIE
DEPTH – 9"
POSITION – ℄ OF LEFT TRACK
DRAWBAR PULL –
WATER BUFFALO ON TOW
PRESSURE, LB/IN²
20
15
10
5
0

Fig. 58.

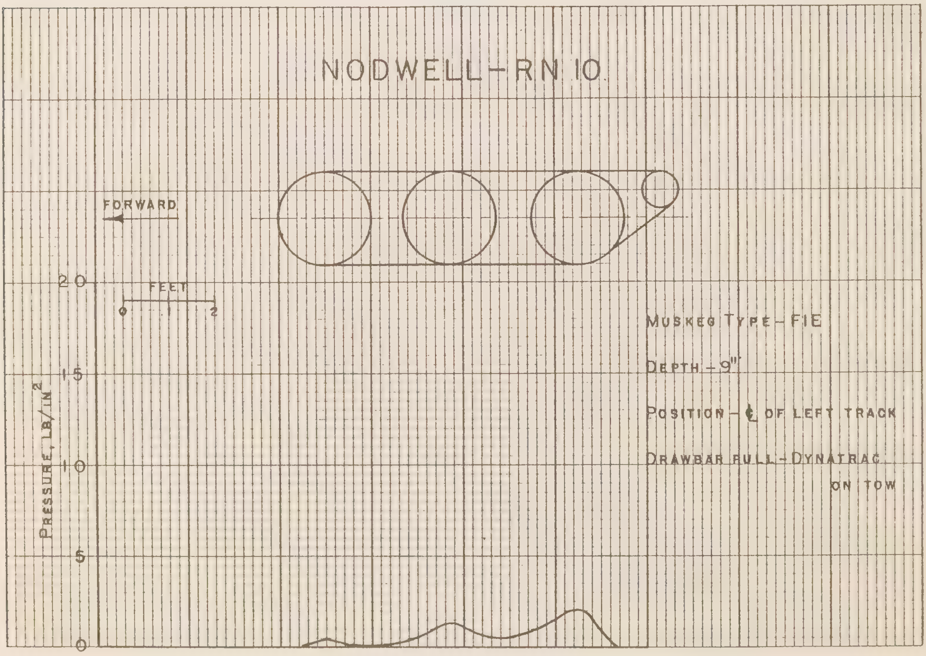

NODWELL – RN 10
FORWARD
FEET
0
1
2
MUSKEG TYPE – FIE
DEPTH – 9"
POSITION – ℄ OF LEFT TRACK
DRAWBAR PULL – DYNATRAC
ON TOW
PRESSURE, LB/IN²
20
15
10
5
0

Fig. 59.

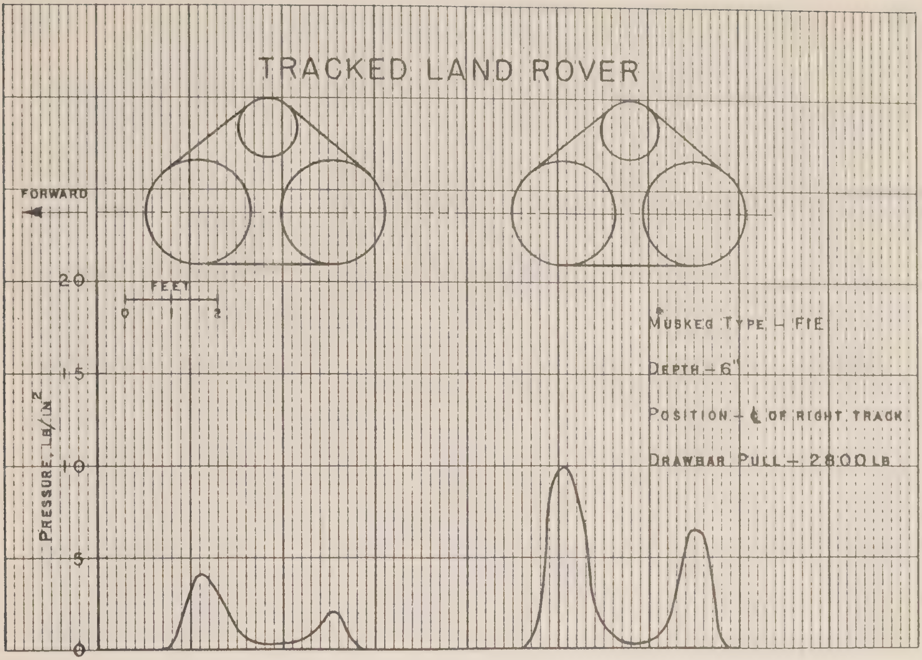

TRACKED LAND ROVER
FORWARD
FEET
0 1 2
PRESSURE, LB/IN^2
20
15
10
5
0
MUSKEG TYPE - FIE
DEPTH - 6"
POSITION - ℄ OF RIGHT TRACK
DRAWBAR PULL - 2800 LB

Fig. 60.

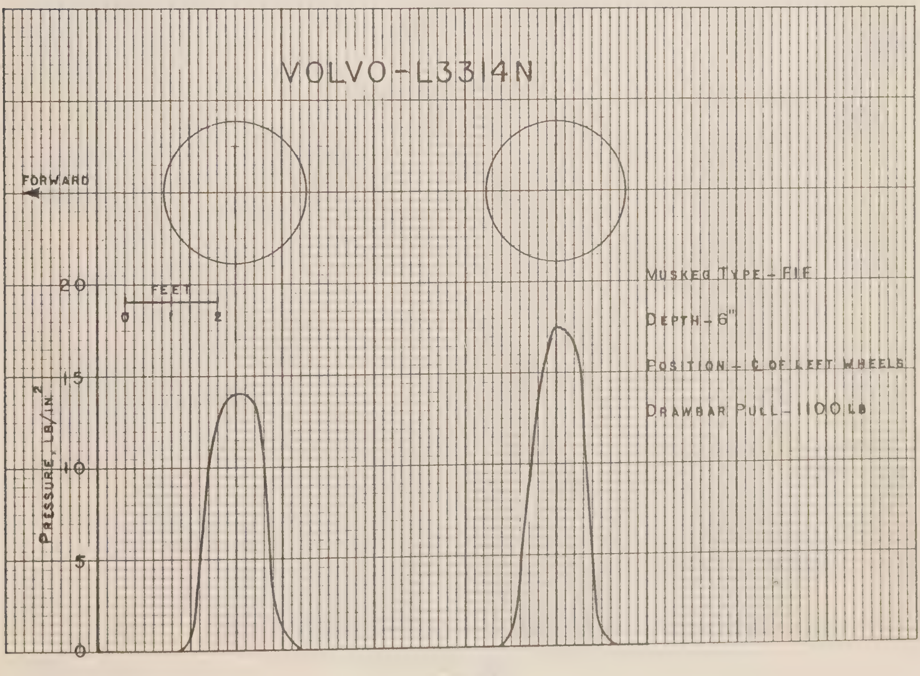

VOLVO-L3314N
FORWARD
FEET
0 1 2
PRESSURE, LB/IN^2
20
15
10
5
0
MUSKEG TYPE - FIE
DEPTH - 6"
POSITION - ℄ OF LEFT WHEELS
DRAWBAR PULL - 1100 LB

Fig. 61.

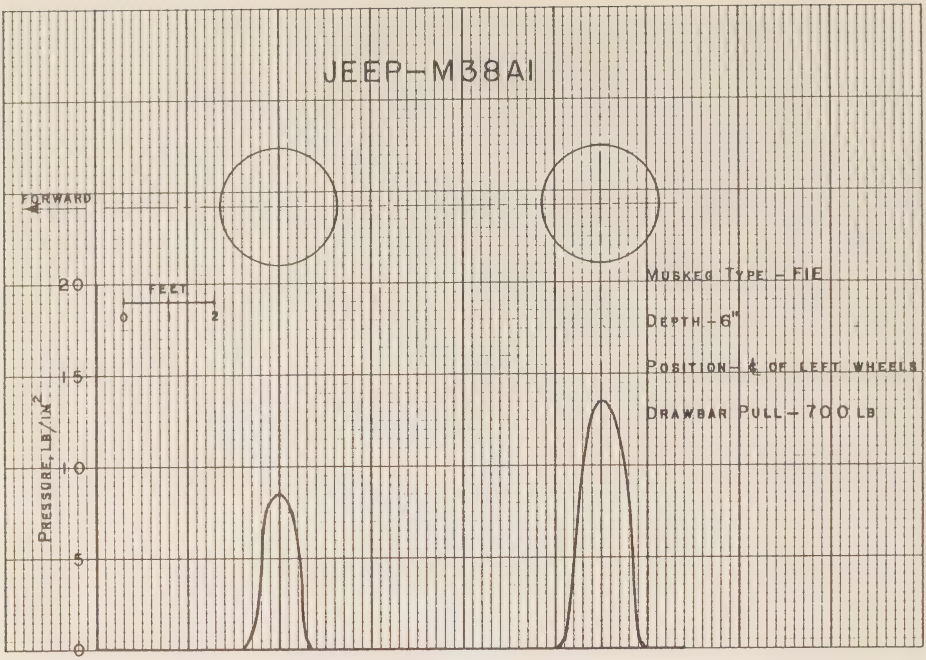

JEEP–M38A1
FORWARD
FEET
0
1
2
20
15
10
5
0
PRESSURE, LB/IN²
MUSKEG TYPE – FIE
DEPTH – 6"
POSITION – ℄ OF LEFT WHEELS
DRAWBAR PULL – 700 LB

Fig. 62.

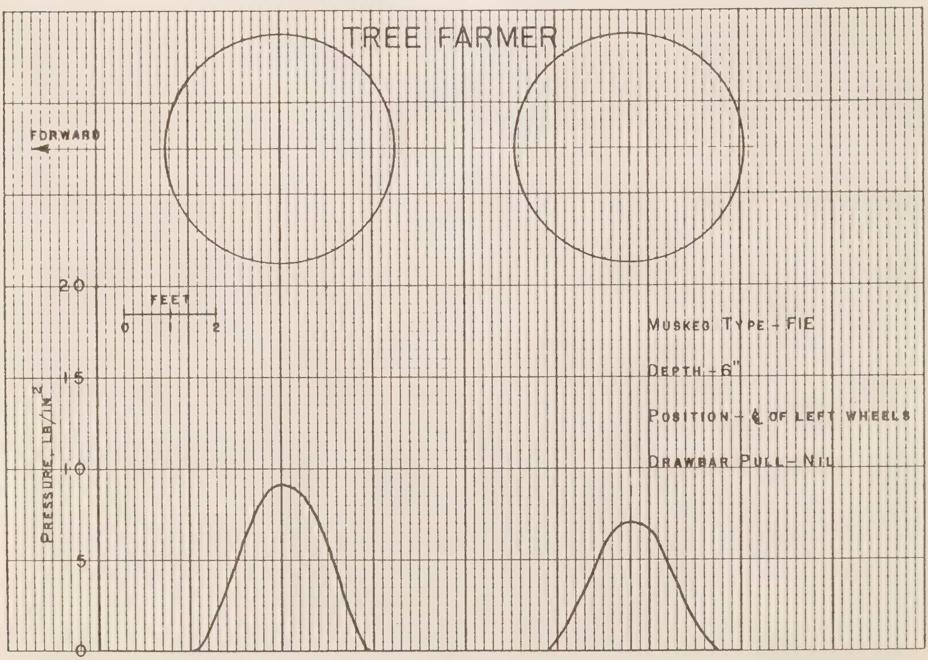

TREE FARMER
FORWARD
FEET
0
1
2
20
15
10
5
0
PRESSURE, LB/IN²
MUSKEG TYPE – FIE
DEPTH – 6"
POSITION – ℄ OF LEFT WHEELS
DRAWBAR PULL – NIL

Fig. 63.

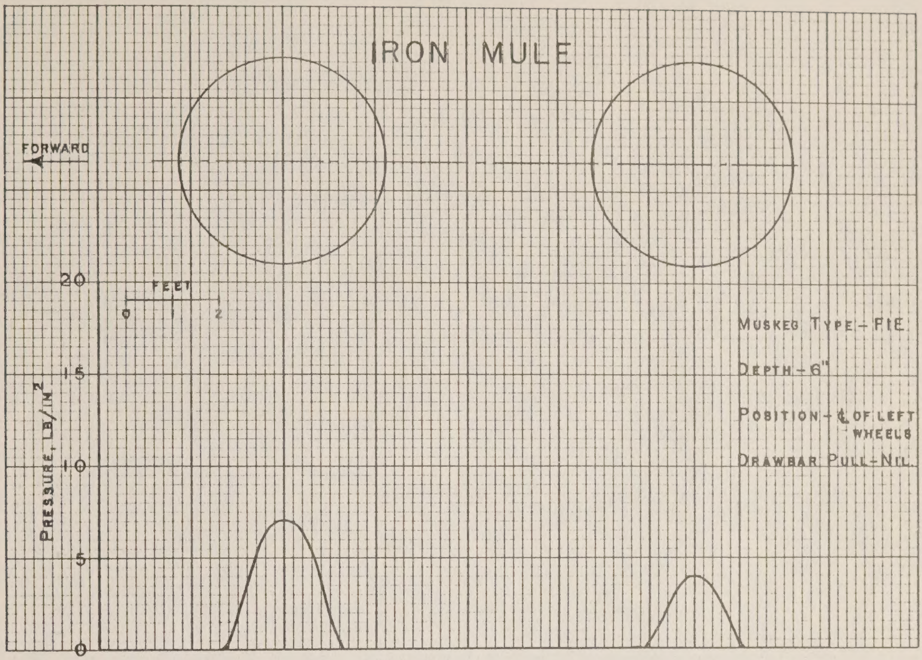

IRON MULE
FORWARD
FEET
0
1
2
20
15
10
5
0
PRESSURE, LB/IN^2
MUSKEG TYPE – FIE
DEPTH – 6"
POSITION – ℄ OF LEFT WHEELS
DRAWBAR PULL – NIL

Fig. 64.

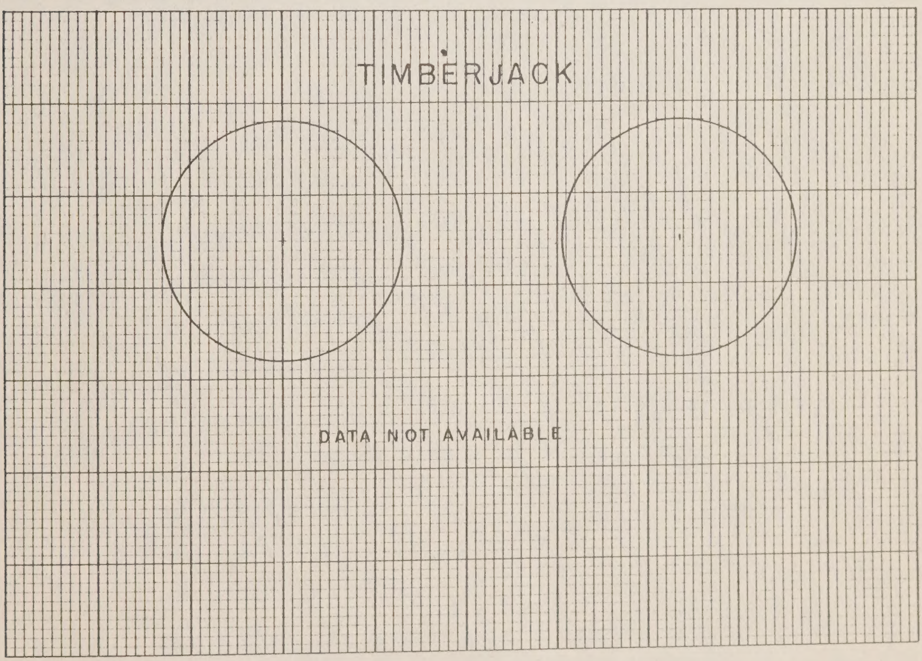

TIMBERJACK
DATA NOT AVAILABLE

Fig. 65.